Cold and hot water plumbing system on living quarters in an offshore platform

by

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Mechanical Engineering Programme
Universiti Teknologi Petronas
in partial requirement for the
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Approved by,

(21 Sep 2011)

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UNIVERSITI TEKNOLOGI PETRONAS
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MAY 2011

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

(ADIB ZULFADHLI BIN SHAHIR)

ABSTRACT

The detailed development for East Piatu (EP) will have a separate Wellhead Platform (WP) with 12 well slots, bridge linked to a manned Central Production Platform (CPP) in 63 meters water depth. Produced oil and gas will be exported via pipelines and tie-in to the export pipelines of Larut-A production platform.

In an offshore platform, living quarters is an accommodation for all offshore workers. It is also equipped with kitchen, canteen, management offices, workshops and recreation areas. The importance of living quarters can be summarized with this statement, an oil platform needs workers, and workers need accommodations. Accommodations are Living Quarters. Good established living quarters is a well functioned living quarters. Well functioned living quarters should have a good piping system. The project focuses on the cold and hot water plumbing system of a living quarter. The living quarters will have 4 levels and each level will be supply with hot and cold water system.

Plumbing system of the cold and hot water of a living quarter on an offshore platform should supply sufficient amount of pressure to maintain and perform effectively. The effectiveness of the plumbing systems will be based on the loading units, pipe sizes, friction loss and head loss and the hot water return water circulation of the plumbing system

Based on this, it has clearly showed the importance of having a good established accommodation in the oil and gas platform for the safety and certainly to make sure the production of the project is maximized. By having a living quarter also save a lot of cost in transportation and also in a way gives a life more comfortable to the workers. By doing this project, the importance of having a good plumbing system on an established living quarters play a major role in the oil and gas industry.

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LIST OF ABBREVIATIONS

PDMS	Plant Design Management System
EP	East Piatu
WP	Well platform
CPP	Central Processing Platform
CPVC	Chlorinated polyvinyl chloride
LQ	Living Quarters
FEED	Front-end Engineering Design
LU	Loading Units
BS2569	British Standard – Specification for sprayed coatings
CAD	Computer Aided Design
HVAC	Heating, Ventilating and Air Conditioning
ASTM D2846	Standard Specification for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Hot- and Cold-Water Distribution Systems
NSF	National Science Foundation
SDR 11	Standard Dimension Ratios
LU	Loading Units
NB	Nominal bore
OD	Outside Diameter
ID	Inside Diameter
E	Elbow
R	Reducer
T_T	Standard Tee through Flow
T_B	Standard Flow Branch Flow
GV	Globe valve
CV	Check Valve
PCV	Pressure Control Valve

LIST OF NOMENCLATURE

bfpd	barrels of fluid per day
cfd	cubic feet per day
ppm	pounds per million
mmscfd	million standard cubic per day
mm	millimeter
lb/sq.ft	pound per square feet
l/s	liters per second
gal/min	gallon per minute
gpm	gallon per minute
ft/s	feet per second
ft^3/min	feet cube per minute
ft/min	foot per minute
psi	pound per square inch
Btu/hr	British thermal unit per hour
$Wm^{-2}k^{-1}$	Watts per meter square Kelvin
Btu/hr-ft	British thermal unit per hour feet
kJ/h	kilojoules per hour
lb/gal	pound per gallon

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CHAPTER 1

INTRODUCTION

1.1 Project Background:

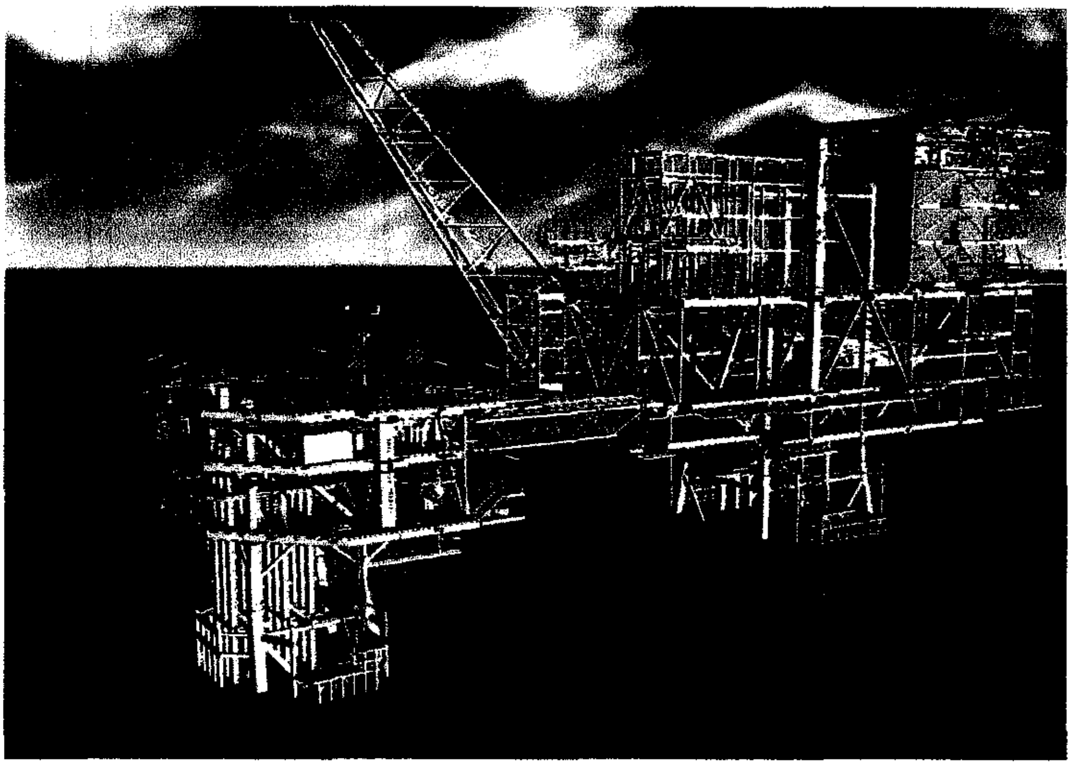


FIGURE 1: East Piatu Development Project PDMS model

The detailed development for East Piatu (EP) will have a separate Wellhead Platform (WP) with 12 well slots, bridge linked to a manned Central Production Platform (CPP) in 63 meters water depth. Produced oil and gas will be exported via pipelines and tie-in to the export pipelines of Larut-A production platform.

The EP Facility is located 275km off the coast of Peninsula Malaysia, approximately 15km north of existing Larut-A production platform. The EP Facility is approximately 255km from Kerteh Helibase and is approximately 280km by sea from Kemaman Supply Base.

The development of EP shall have 8 single oil producers. The key design production rates are:

- Maximum Fluid Rate: 15,000bfpd
- Maximum Oil Production: 15,000bfpd
- Maximum Water Production: 10,000bfpd
- Associated Gas Production: 15mmscfd
- Gas Lift: 8mmscfd

The EP Facility shall have test and production separation, gas conditioning facilities, export pumping and custody transfer metering for export quality oil and sales gas to Larut-A facility.

Gas compression facilities shall be provided to compress up to 30mmscfd of gas for gas export and gas lift requirement from two with a good efficiency compressors. Export pipelines for oil and gas shall be provided for export to Larut-A platform.

Utility services shall be provided for produced water treatment and disposal to a level of oil in water of 40 ppm maximum/20ppm average. The EP complex will be powered by gas turbine driven generators.

The facility will be permanently manned with up to 30 personnel (normal operations) and be expandable (by virtue of a number of cabins having additional berths) to 42 personnel in time of hook up, walkovers or other major maintenance campaigns. The living quarters, safety and evacuation facilities shall cater for 42 personnel level. A helideck with refueling facilities shall be provided on the CPP and boat landing platforms shall be provided on the WP and CPP. This project will focus on the cold and hot water plumbing system of the living quarters. The living quarters will have 4 levels and each level will be supply with hot and cold water system.

Cold and Hot Water System Description

The pressurized water supply to the living quarters shall be supplied from potable water storage tank (T-640A/T-640B) located on the upper cellar deck of EPCPP Platform. The locations of the tanks are illustrated in Appendix A where the piping and instrument diagram of the location can be shown. All plumbing system within the inside of the Living Quarters to the tie in point below the living quarters shall be the responsibility of the contractor scope of works. The plumbing system shall be tested and re-commissioned and shall be ready for immediate offshore connection.

The cold water supply distribution system shall supply all the cold water demands to the following:-

Table 1.1: Cold Water Distribution

Level 1	Dining area galley, laundry, common toilets at locker room, drinking fountain
Level 2	Living quarters cabin, sink at linen room, taps at ablution for prayer room, drinking fountain
Level 3	Living quarters cabin, sickbay, sink at linen room, drinking fountain
Level 4 (roof level)	Drinking fountain, gymnasium

Hot water shall be supplied from the hot water calorifiers located at the living quarter's roof level adjacent to the gymnasium and distributed throughout the living quarters. Potable hot water shall supply to serve the following:-

Table 1.2: Hot water Distibution

Level 1	Drink area galley, Laundry, common toilet at locker room
Level 2	Living quarters cabin, sink at linen room,
Level 3	Living quarters cabin, sickbay, sink at linen room
Level 4 (roof level)	Gymnasium

The hot water calorifiers must be able to cope with the daily demand. Each shall be capable of supplying hot water at a temperature of 60°C maximum in accordance with the following criteria:-

- Daily demand of 115 liters per person per 24 hours.
- Storage capacity of 35 liters per person.
- Heat - up period of 1 hour.

1.2 Problem Statement:

1) The importance of piping system of the living quarters in an offshore platform usually being neglected.
2) The piping system will need a very high pressure to make sure all its component function efficiently if the system is wrongly build.
3) The piping system can be facing a water hammer problem which due happened to excessive pressure in the pipings if wrong pipe sizes are used.
4) The hot water calorifier specification of the recovery time, cost, power requirement, economical temperature, reliability and space will be considered when choosing the calorifier.
5) The toilet valve which is commonly used right now is flush valve that nreeds 45 psi to 60 psi to function, which is high and costly.

1.3 Objective and Scope of study:

This project focuses on the 5 objectives.

- Design a complete and well-functioned plumbing system for the living quarters and needing minimal pressure.
- Analyzing the plumbing system consisting of hot and cold water system
- Calculating the loading unit and flow rate, to correctly size the pipe to avoid water hammer in the system.
- Comparing and choosing the most suitable hot water calorifier.
- Analyzing flush valves and the selection of each valve

The project will basically provide the scope, project data, design criteria and technical requirement for the living quarters utility piping for the project. The calculation data of each hot and cold water system for each floor will be taken using the suitable theory and equations.

The project basically taking into account about:

- <u>Piping System</u>

  Designing of the piping system of the oil platform

- <u>Loading units (LU)</u>

  Loading units are determined for each floor from the system of the pipe.

- <u>Rate of Flow or Duty</u>

  By using the loading units rating calculated, the determined of flow rate in gal/m at each branch of pipes at each floor deck is known.

- <u>Effective length of Pipe</u>

  The diameter of pipe necessary to give the required flow rate is considered, taking in account the losses through fittings such as elbows tees, taps and valves etc.

- <u>Determination of Pipe Diameter</u>

  The diameter of the pipe for a given flow rate is calculated taking into consideration the allowable loss of head per foot run of effective pipe length. The calculations presented in this report have taken into account the furthermost hydraulic design point until the tie - in points below the Level 1 of the Living Quarters.

- <u>Friction Loss</u>

  Friction loss calculation through straight pipes and fittings for hot and cold water system

- Heat loss of each pipe

  Hot water recirculation sizing factor hydraulic calculations for sizing the CPVC pipe and fittings shall be calculated using a Hazen William C factor of 150

- Decision Matrix

  Decision making on the pipe material and hot water calorifier are decided by using the decision matrix method.

CHAPTER 2

LITERATURE REVIEW

2.1 Living Quarter Platform or LQ

Living quarter platform is a type of platform where living quarter is installed. This living quarter is an accommodation for all offshore workers. It is also equipped with kitchen, canteen, management offices, workshops and recreation areas. Typically, there is a helipad installed above the LQ for personnel transportation as well.

According to Richard Slawsky, "It is no secret that deepwater drilling activity in the Gulf of Mexico is at a record level", said Glenn Aguilar, vice president of U.S. operations for Duffy & McGovern. As a result, demand for additional offshore accommodation is understandably on the rise and the region has become one of the main growth areas. There are now more than 20 companies in the region compared with around eight in the same period last year that focused in living quarters. [1]

Based on this, it has clearly showed the importance of having a good established accommodation in the oil and gas platform for the safety and certainly to make sure the production of the project is maximized. By having a living quarter also save a lot of cost in transportation and also in a way gives a life more comfortable to the workers. By doing this project, the importance of having a good plumbing system on an established living quarters play a major role in the oil and gas industry.

2.2 Front-end Engineering Design (FEED)

Front-end engineering design (FEED) is a series of design optimization to refine the selected design concept. Optimizations will lead to a finalizing the production scenario, tie-in/commingling scenario, energy and material requirement, utility and structure material requirement etc. FEED is a study used to analyze the various technical options for new developments with the objective to define the facilities required. [2]

The traditional approach to FEED is to separate conceptual design from basic engineering activities, and to execute various tasks sequentially. Conceptual design is primarily performed by process engineers, who generally work with a variety of stand-alone software tools and applications, such as process simulation programs, heat exchanger design programs, and equipment sizing and data sheets, sketching the flow diagrams and identify critical control requirements on preliminary piping and instrumentation diagrams.

All of these activities are typically accomplished using discrete workflows with little or no reuse data. Each specialist communicates the data he or she is responsible for in the form of sketches, files and reports, and all of these documents are then collectively passed on to the basic engineering phase. [3]

Most of the overall project costs for an industrial plant project are defined at a very early planning stage, referred to as the front-end engineering design (FEED) phase. The decisions taken during this project phase significantly influence the subsequent layout tasks and are crucial for the practical suitability, performance and cost-effectiveness of a plant or component.

2.3 Water Heater Calorifier

Water heating is a thermodynamic process using an energy source to heat water above its initial temperature. Typical domestic uses of hot water are for cooking, cleaning, bathing, and space heating. In industry, both hot water and water heated to steam have many uses. Domestically, water is traditionally heated in vessels known as water heaters, kettles, cauldrons, pots, or coppers. These metal vessels heat a batch of water but do not produce a continual supply of heated water at a preset temperature. The temperature will vary based on the consumption rate of hot water, the more capacity of the hot water; the faster the water is cooled.

As for the oil and gas industry, especially on the platform of the oil rig, for the living quarters the water calorifier that are usually been used in a basic structure. These high quality calorifiers are specially designed for maritime use and provide a sea going ship or offshore rig with a very reliable hot water supply. As a standard, the calorifiers are fabricated as a vertical boiler unit, made of stainless or carbon steel with a copper inner casing, and include insulation and protective plating.

In this project, the water heater calorifier will be selected and chosen based on the given factors. The hot water calorifer will be applied at the living quarters and be used accordingly to their specification of the recovery time, cost, power requirement, economical temperature, reliability and space will be considered when choosing the calorifier.

When domestic hot water is required in volume the range of storage calorifier offers ideal solution stored water is heated indirectly by a primary medium usually by an internal U-tube battery. Alternatively electric immersion heaters offer a clean and efficient primary heat source. [4]

<u>Factors affecting the choice of storage calorifiers are:</u>

i. Cost – storage calorifiers are often the most economical water heating solution
ii. Low primary power requirement – the stored hot water meets high peak demands relatively low primary power, keeping the primary supply capital cost lower than in instantaneous or semi-storage systems.
iii. Economical Temperature Control – simpe on/off temperature control is often all that is required
iv. Reliability – storage calorifiers are robust and uncomplicated, giving excellent reliability and availability.

v. Space – an instantaneous water heater may be more compact than a storage calorifier, but requires a larger primary heat source, negating some of the space saving.

vi. Heat loss – correct insulation of the calorifier results in low heat loss. Compared to instantaneous heaters the low, steady primary heat requirement reduces inefficient boiler cycling. Primary pipe-work is smaller and loses less heat. Electrically heated storage calorifiers, using off-peak electricity, give savings in running costs.

Storage volume and Recovery time

Storage calorifier volume and recovery time determine output. Recovery time is the time and the calorifier take to heat up from cold under zero demand. Long recovery times require low primary power and vice versa.

The tube battery (or immersion heater) is mounted low down in the calorifier. The contents are heated almost uniformly by natural convection. During draw-off the calorifier design minimizes mixing of incoming cold water with the hot water above. If draw-off is too high the hot water layer becomes exhausted and the water drawn becomes exhausted and the water drawn will be too cool. It is important to select an adequate storage volume to meet anticipate demand. [5]

Materials of hot water calorifier

Copper Shells

Solid copper has proved to be a reliable and economical non ferrous metal for the construction of hot water storage vessels. It is used extensively throughout the world due to its long life and an ability to withstand most concentrations of corrosive elements found in domestic hot water. Modern fabrication has further improved the quality of welded joints and copper alloy fittings can be selected to avoid dezincification. The mechanism which protects copper from corrosion is the formation of a copper oxide on the metal surface. There are very few sources of fresh water which are sufficiently aggressive to prevent the formation of this oxide film. This sacrificial anode deposits an aluminium compound on the copper surface, which gives permanent protection and does not require further anodes to be fitted.

Steel Copper Lined

The fabrication of large high pressure cylinders from solid copper is normally considered uneconomical and has generally been superseded by the alternative construction of steel shells lined with copper. This arrangement combines the strength of a steel vessel with the superior corrosion resistance of copper. The lining is attached to the steel shell at points around the circumference and is pulled back by vacuum during manufacture to produce a good fit. Joint construction is such that longitudinal and lateral movement due to temperature and pressure changes can be accommodated without additional compensation.

Galvanized Steel Shells

The coating of steel with zinc by hot dipped galvanizing or metal spray has proved good protection for hot water storage cylinders over many years providing the water is hard. It is essential that a deposit of lime forms rapidly on the surface with the galvanized parts before the zinc is dissolved or deposited other parts of the system by electrolytic action. Local knowledge will generally decide whether a galvanized cylinder is suitable for the water conditions on site, but guidance from the water supply authority should be sought if there is any doubt. To extend the life of the zinc coating and allow further time for the scale deposit to form cylinders are supplied with magnesium anodes.. The life of a steel calorifier sprayed with zinc is comparable to a galvanized unit. The use of copper pipe work in association with a galvanized cylinder is to be avoided, particularly on the hot water side if there is a secondary return to the shell. Apart from electrolytic action between copper and galvanized steel connections there is a serious risk of damaging the zinc surface. This is caused by minute particles of dissolved copper settling on the galvanized surface and producing local cells which dissolve the zinc coating and expose the steel shell beneath.

Stainless Steel

Austenitic Stainless Steel 316L is suitable for storage calorifiers, it contains 18% Chromium, 8% Nickel, 2-3% Moybdenum and has a low carbon content 0.003% to improve corrosion resistance after welding. The passivity and general corrosion resistance of Austenitic stainless steel is well known but they do suffer from chloride attack. This can happen in the form of crevice, stress or pitting corrosion. Good manufacturing techniques and a correct post manufacture treatment to restore the stainless steel to its original properties can reduce the susceptibility but cannot completely prevent corrosion attack. Hot water containing quite small quantities of chlorides has been found to be quite aggressive to stainless steel at calorifier operating temperatures. Therefore unless local experience has shown that Austenitic stainless steel is suitable for storing hot water other superior grades of stainless steel. [6]

2.4 Pipe Materials selection

Two most common materials currently used for potable water supply lines are copper and plastic. [7]

Copper

Copper is used most often in plumbing piping because it offers numerous advantages:

i. Corrosion resistance and low friction loss
ii. Smaller in diameter and can be used in tight places
iii. Copper inhibits bacteria growth, therefore the water is safe to drink
iv. More resistant to flame than CPVC pipes
v. Copper pipes also are more prone to withstand earthquakes
vi. Provide better form fitting than CPVC pipes
vii. Life expectancy of copper piping is indefinite unless unusual water conditions or manufacturing defects are present

The disadvantages of copper pipes are higher cost, condensation concerns, heat conductivity, system noise and tube can kink.

Plastic (CPVC)

Plastic pipes CPVC used solvent welded or glued fittings. Plastic pipes offer many advantages over copper:

i. Plastic pipes are easy to work with and connections can be made without soldering
ii. It is the most lightweight that makes it easier to install
iii. Has lower cost
iv. Can withstand higher water pressure than the copper
v. Non-conductive, will not rust, and is not as conducive to condensation
vi. Less noisy at higher water pressure levels
vii. Self-insulating which means it can handle hotter temperature water

The disadvantages of plastic pipes are plastic pipes are bulky and often do not fit in tight places as well as copper. Fitting failures and leakage may occur because of poor workmanship. Plastic pipes contain volatile compounds which are harmful to the environment. Even though they can withstand hot water temperatures, they are less flame resistant. That is one of the biggest disadvantages.

2.5 Decision Matrix

To decide which material to use and which hot calorifier to be chosen, decision matrix method is used. Decision Matrix is also called Pugh matrix, decision grid, selection matrix or grid, problem matrix, problem selection matrix, opportunity analysis, solution matrix, criteria rating form, criteria-based matrix.

A decision matrix evaluates and prioritizes a list of options. The team first establishes a list of weighted criteria and then evaluates each option against those criteria. This is a variation of the L-shaped matrix. [8]

A decision matrix is chosen because the choices of copper pipes and CPVC pipes must be narrowed to only one choice. This decision must also be made on the basis of several criteria and this decision also be made after the list of options has been reduced to a manageable number by list reduction. The procedures of making the Decision Matrix are:

i. Discuss with client the criteria appropriate to the situation.
ii. Refine the list of criteria and identify any criteria that must be included and any that must not be included. Reduce the list of criteria to those that are most important. Tools such as list reduction and multivoting may be useful here.
iii. Assign a relative weight to each criterion; based on how important that criterion is to the situation. Do this by distributing 10 points among the criteria. The assignment can be done by discussion and consensus. Or each party involve can assign weights, then the numbers for each criterion are added for a composite team weighting.
iv. Draw an L-shaped matrix. Write the criteria and their weights as labels along one edge and the list of options along the other edge. Usually, whichever group has fewer items occupies the vertical edge.
v. Evaluate each choice against the criteria. There are three ways to do this:

Method 1: Establish a rating scale for each criterion. Some options are:

1, 2, 3:	1 = slight extent, 2 = some extent, 3 = great extent
1, 2, 3:	1 = low, 2 = medium, 3 = high
1, 2, 3, 4, 5:	1 = little to 5 = great
1, 4, 9:	1 = low, 4 = moderate, 9 = high

The rating scales are made sure to be consistent. Criteria are worded and the scales are set so that the high end of scale (5 or 3) is always has the tendency to be chose : most impact on customers, greatest importance, least difficulty, greatest likelihood of success.

Method 2: For each criterion, rank-order all options according to how well each meets the criterion. Number them with 1 being the option that is least desirable according to that criterion.

Method 3, Pugh matrix: Establish a baseline, which may be one of the alternatives or the current product or service. For each criterion, rate each other alternative in comparison to the baseline, using scores of worse (–1), same (0), or better (+1). Finer rating scales can be used, such as 2, 1, 0, –1, –2 for a five-point scale or 3, 2, 1, 0, –1, –2, –3 for a seven-point scale. Again, be sure that positive numbers reflect desirable ratings.

vi. Multiply each option's rating by the weight. Add the points for each option. The option with the highest score will not necessarily be the one to choose, but the relative scores can generate meaningful discussion and lead the team toward consensus

2.6 Computer Aided Design (CAD)

Computer-Aided Design (CAD) is the use of computer software and systems to draft, model, and edit architectural or engineering designs. Tedious manual drafting process is replaced with an automated process by using the CAD programs. Two-dimensional CAD software is used for basic drafting and drawing applications while designers are able to apply multiple light sources such as rotating objects in three dimensions, and viewing designs in rendered form from any angle with the Three-dimensional CAD software. [9]

According to Haresh Khemani, implementing CAD systems increases the productivity of the designer as they assist designers in visualizing the final product that is to be made. Another advantage of using CAD software is that the documentation of designing can be created conveniently. Apart from that, designing data can be saved easily with CAD software for future reference. This reduces the usage of time and money as certain components do not have to be redesigned. [10]

Several industries and practices have been revolutionized with the help of knowledge sharing through the online communities. Other than the CAD library of products and services offered by industrial suppliers, support is also available from professionals who can offer advice. The field of knowledge and capabilities of the computer drafting environment has expanded by the Internet's collaborative nature. On the whole, almost every engineering discipline such as Civil Engineering, Mechanical Engineering, Electrical Engineering, Electronics, Engineering, Architectural Engineering, Aerospace, Automobile, Manufacturing, Production, Plumbing, Piping, and Heating, Ventilating and Air Conditioning (HVAC) find CAD drawings and a CAD library essential. [3]

Basically, the project will be using AUTOCAD mostly in understanding the current living quarters design. AUTOCAD will also be used to draw the nodes, fittings and pipes route. Most of the data for the calculations will also be getting from this software, as example the pipe length and size of the calorifier, the room size and etc. The software will also been used to redesign the living quarters and designing of the plumbing system. By using CAD methods, the full review of the design can also be known which will make it easier for this project to succeed.

2.7 Hazen-William C Factor

The Hazen–Williams equation is an empirical formula which relates the flow of water in a pipe with the physical properties of the pipe and the pressure drop caused by friction. It is used in the design of water pipe systems such as fire sprinkler systems[1], water supply networks, and irrigation systems. It is named after Allen Hazen and Gardner Stewart Williams.

The Hazen–Williams equation has the advantage that the coefficient C is not a function of the Reynolds number, but it has the disadvantage that it is only valid for water. But this disadvantage can be ignored because this project is basically taking into account of water which is for potable water system. Also, it does not account for the temperature or viscosity of the water. As in this project earlier, the calculations for the water recirculation sizing factor hydraulic for sizing the CPVC pipe and fittings shall be calculated using a Hazen William C factor of 150. [11] This is due to the system that uses the FlowGuard Gold® pipe and fittings as the main pipe distributor. While both copper and CPVC use a C factor of 150 for new systems, as copper ages, the internal diameter of the pipe is subject to pitting and scaling causing pressure loss to increase over time. Since a FlowGuard Gold® system is not subject to pitting and scaling, the C factor will remain constant as the system ages. This can be confirmed by the attachment attached in Appendix B.

2.8 FlowGuard Gold® pipe and fittings

FlowGuard Gold® pipe and fittings, Design and Installation Manual for Water Distribution Services will be one of the main references for this project. The design manual provides instructions for handling and installing a FlowGuard Gold® water distribution system as well as information regarding system design and for this project that is the hot and cold water plumbing system of the living quarters. It is intended as a supplement to basic, fundamental knowledge relating to the installation and/or repair of CPVC water distribution systems. It is also intended to supplement installation instruction published by manufacturers of pipe and fittings. FlowGuard Gold® pipe and fittings are produced to meet the requirement of ASTM D2846, so this manual can be trusted as a reliable guide for this project. FlowGuard Gold® pipe, fittings and solvent cement are also certified by NSF international for use with potable water (NSF-pw). The NSF certification is applicable for all water pH levels. [11]

ASTM D2846 is Standard Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) plastic Hot- and Cold-Water Distribution Systems. [12] This specification covers requirements, test methods, and methods of marking for chlorinated poly (vinyl chloride) plastic hot- and cold-water distribution system components made in one standard dimension ratio and intended for water service up to a certain temperature. These components comprise pipe and tubing, socket-type fittings, street fittings, plastic-to-metal transition fittings, solvent cements, and adhesives. The components are intended for use in residential and commercial, hot and cold, potable water distribution systems. The products covered by this specification are intended for use with the distribution of pressurized liquids only, which are chemically compatible with the piping materials. CPVC 4120 pipe, tubing, and fittings shall be classified by a single standard dimension ratio which shall be SDR 11, by a certain maximum continuous use temperature and by a certain diameter range for nominal pipe or tubing. CPVC plastic-to-metal transition fittings intended for use up a certain temperature are classified on the basis of resistance to failure by thermo cycling. The chlorinated poly (vinyl chloride) plastics are categorized by two criteria: basic short-term properties and long-term hydrostatic strength. These short-term properties include mechanical strength, heat resistance, flammability, and chemical resistance which shall be determined after performing different tests. A test shall also be conducted in order to determine the long-term hydrostatic strength of CPVC 41 pipe, tubing, and fittings.

2.9 Flushing mechanisms for the water closets in the living quarters

Water closets, urinal and bidets general have two parts which are, a receptor for waste which includes the drain system and a flushing or water supply mechanisms. These plumbing fixtures are generally grouped according to their flushing action, which affects the bowl type, flushing mechanism and mounting method. [13] Common plumbing fixture water supply types include the following flushing mechanism:

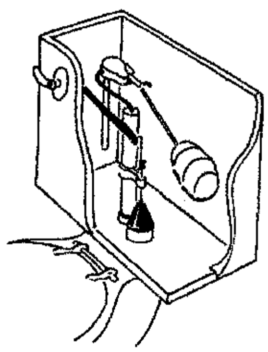


Figure 2: Basic example of flushing mechanisms for gravity tank

Gravity flush tank

Water enters the tank through a ball cock valve and is stopped when the float valve reaches a predetermined level. The handle raises the flapper to release the in the tank into the fixtures and stops when the flapper closes. Gravity flush tanks only require 10 psi water pressure.

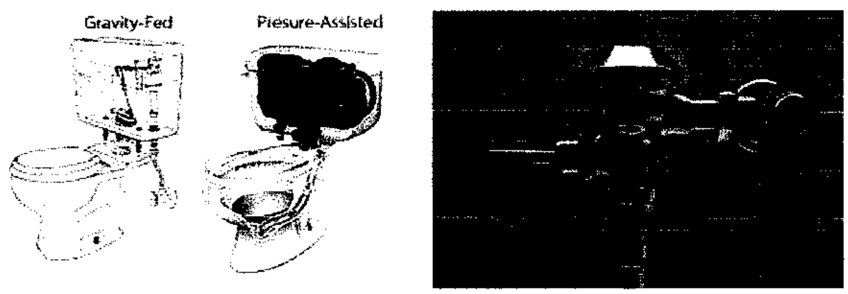
Pressure-assisted flush tank

Water enters a pressure tank installed inside an outer tank, partially filling the tank and compressing the air inside. When flushing is started, the air pressure causes the quick release of water into the feature. Pressure-assisted flash tank require 30 psi water pressure.

Flush valve

Flush valves are available in a wide variety of manual and automatic operation features, some with infrared and other proximity sensors. Once flushing has started, a measured quantity of water is quickly introduced into the fixture. A flush valve requires a minimum of 25 psi water pressure to operate and can go up to 65 psi..

In this project, the end results will be compared using 3 different kinds of flush tanks. The results obtained will see which tanks suit the most in the system.



a) b) c)

Figure 3: Flushing Mechanism: a) Gravity flush tank, b) Pressure-assisted tank and c) flush valve

2.10 Hot Water Return Piping System Recirculation Sizing

A circulation system is a system of hot water supply pipes and hot water return pipes with appropriate shutoff valves, balancing valves, circulating pumps, and a method of controlling the circulating pump.

The method for selecting the proper size of the hot water return piping system and the recirculation pump require engineering judgment. From the design of the hot water supply and hot water return piping systems, the parameters for total developed length, prompt delivery of hot water to fixtures, and velocities in pipe lines can be known. Assumptions about the sizes of the hot water return piping can be done from here.

The piping diagram in Appendix F of the hot water supply system and the assumed return system should show the piping sizing and approximate lengths. From this piping diagram the hourly heat loss occurring in the circulated portion of the hot water supply and return systems can be determined.

Next, the heat loss in the hot water storage tank is determined. The total hot water system energy loss in British thermal units per hour (watts) is calculated. This total hot water system energy loss is represented by Q in the following equation.

Heat losses from storage type water heater tanks are not normally included in the hot water piping system heat loss because the water heater capacity takes care of this loss, whereas pumped hot water has to replace the piping convection losses in the piping system. [16]

$$Q = 3600\ R\ W\ C\ \Delta T$$

Where,

3600 = sec/h

Q = piping heat loss, Btu/hr (kJ/h)

R = flow rate, gpm (l/s)

W = weight of heated water, lb/gal (kg/l)

C = specific heat of water, Btu/lb/°F (kJ/kg/K)

ΔT = change in heated water temperature (temperature of leaving water minus temperature of incoming water, represented in this manual as $T_h - T_c$, °F [K])

Therefore

Q = c (gpm × 8.33 lb/gal) (60 min/h) (°F temperature drop)

= 1(gpm) × 500 × °F temperature drop

Making the equation to become,

$$\text{Hot re-circulating pump flow rate, gpm} = \frac{\text{system heat loss (Btu/hr)}}{500 \times \text{°F temperature drop}}$$

CHAPTER 3

METHODOLOGY

3.1 METHODOLOGY

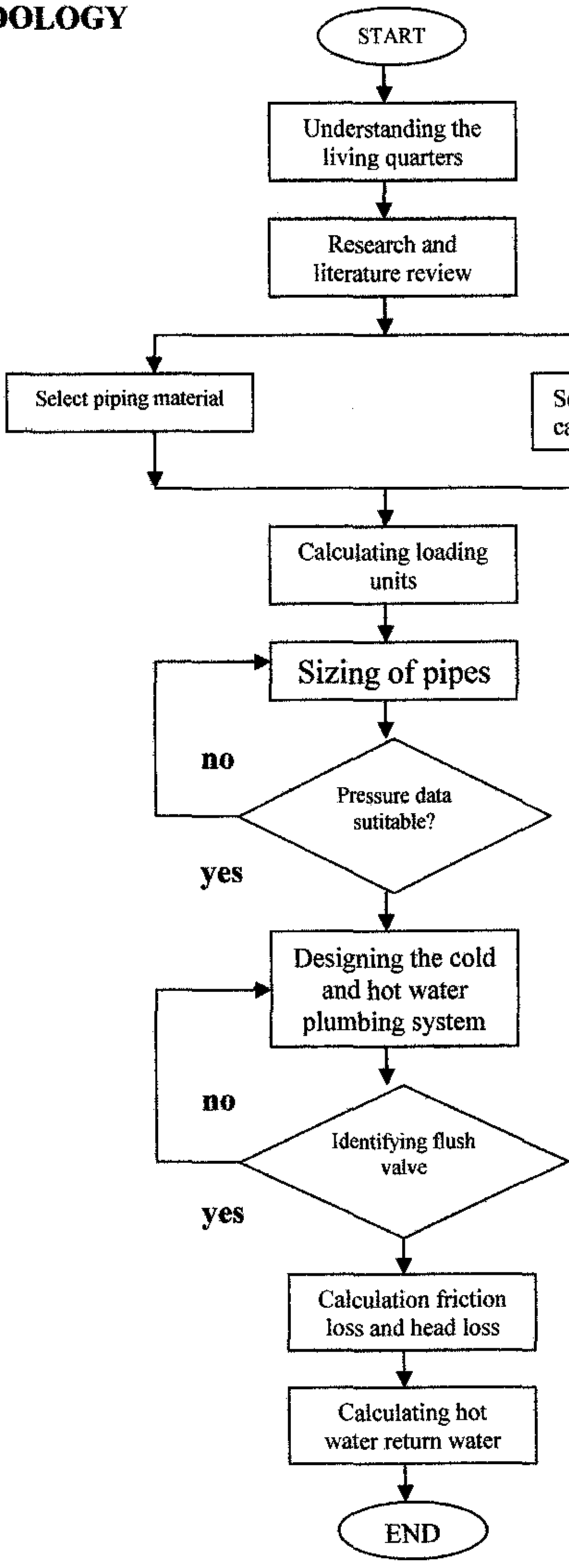


Figure 4: Methodology Method

3.2 Gantt Chart

No	Details	Week 1	2	3	4	5	6		7	8	9	10	11	12	13	14
1	Selection of Project Topic	■						MID SEMESTER BREAK								
2	First meeting with supervisor		■													
3	Preliminary Research work															
	a) Research the detail about Living Quarters		■	■	■	■	■		■							
	b) Research about Piping system		■	■	■	■	■		■							
	c) Research about hot water calorifier and flush valve		■	■	■	■	■		■							
4	Preliminary Report preparation			■	■											
5	Submission of Preliminary Report (20 August 2010)				●											
6	Seminar 1					■	■		■							
7	Progress report preparation								■							
8	Submission of Progress Report								●							
10	Get familiar with the principal and equation involved								■	■	■	■				
11	Discussion for hot water colorifier system									■	■	■				
12	Loading unit determination for cold water system											■	■	■	■	■
13	Loading unit determination for hot water system											■	■	■	■	■
14	Determination of total flow for hot and cold water system										■	■	■	■		
15	Submission of Interim Report Final Draft														●	
16	Oral Presentation preparation													■	■	
17	Oral Presentation (Week 14)															●

Figure 5: Gantt chart for FYP 1

● Suggestion milestone

■ Process

No	Details	Week															
		1	2	3	4	5	6		7	8	9	10	11	12	13	14
1	Piping system design pipeline and length	■	■	■				MID SEMESTER BREAK								
2	Hot water calorifier comparison and pipe materials selection				■	■										
3	Project work continues					■	■		■							
	a) Heat loss for hot water recirculation sizing pipes					■	■		■							
	b) Determination of heat loss for horizontal pipe					■	■		■							
	c) Determination of heat loss and flowrate in each level					■	■		■							
4	Submission of progress report									●						
5	Project work continues								■	■	■	■	■	■	■	■
	a) Determination of total friction loss for hotwater return water								■	■	■	■	■	■	■	■
	b) Determination of total friction loss for cold and hot water system								■	■	■	■	■	■	■	■
	c) Flush valve substitution								■	■	■	■	■	■	■	■
6	Poster exhibition												●			
7	Submission of draft report													●		
8	Submission of dissertation (soft bound)														●	
9	Submission of technical paper														●	
10	Oral presentation															●
11	Submission of Dissertation (hard bound)								During study week							●

● Suggestion milestone

■ Process

Figure 6: Gantt chart for FYP 2

3.3 Brief layout on the living quarters plumbing system

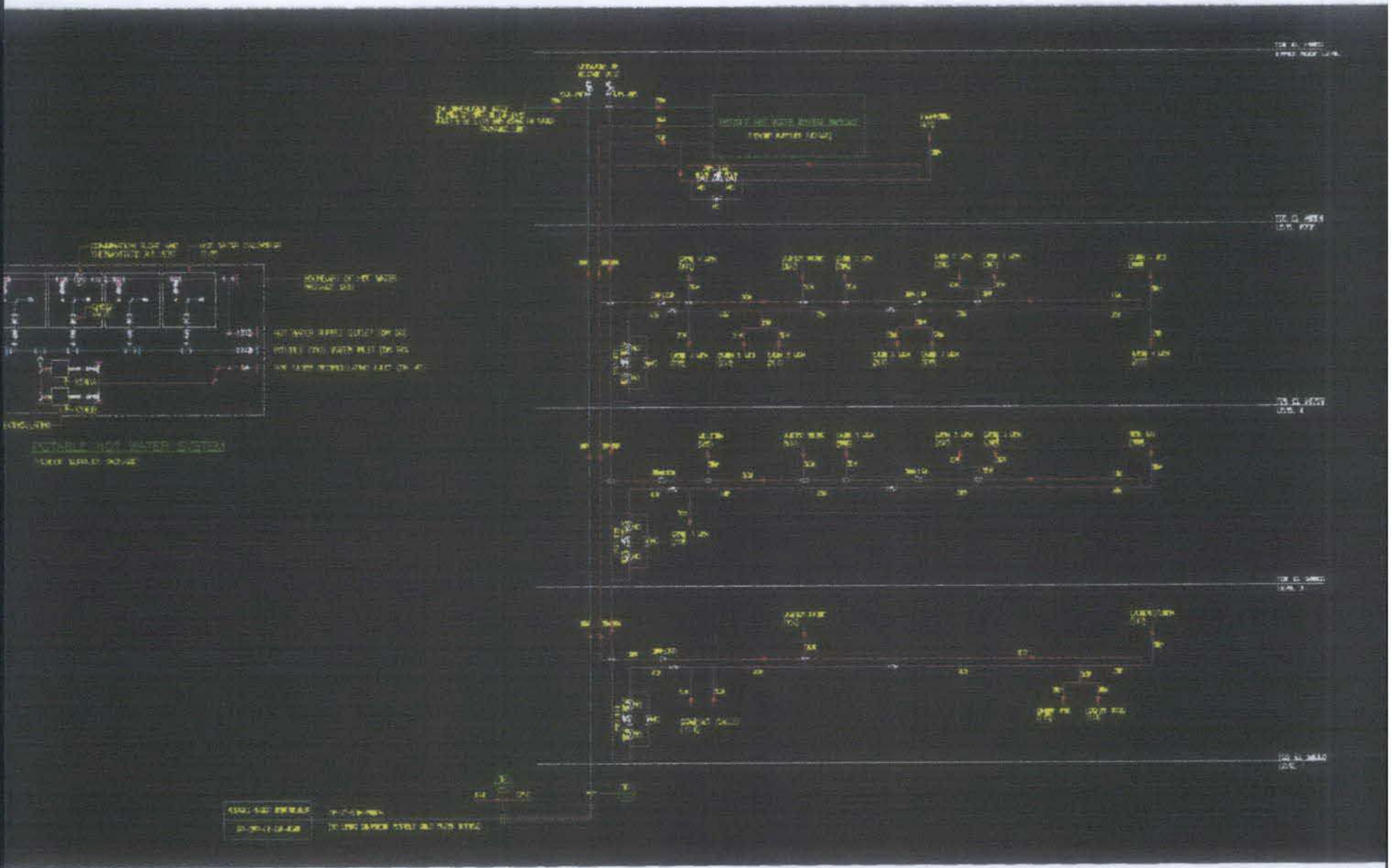


Figure 7: Brief Layout on the living quarters plumbing system

Figure 7 briefly show how the living quarters plumbing system will be design and also show the tie-in where the pressure need to be found to make sure the living quarters is fully function. For more detailed and clearer explanation can be referred to Appendix F.

3.4 Design of hot water calorifier

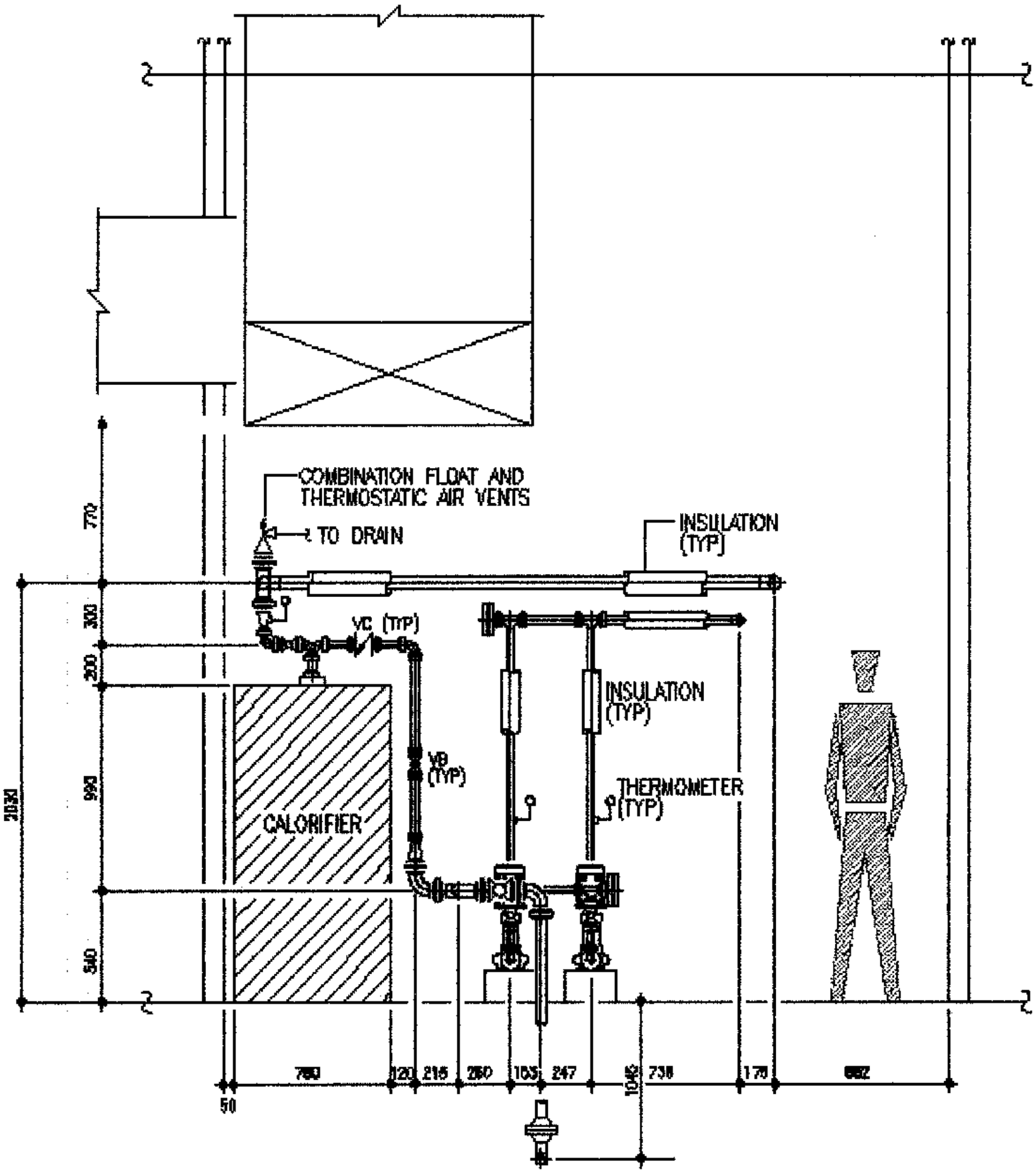


Figure 8: Hot water calorifier

Figure 8 is the specifications, pipe length and sizing of hot water calorifier that the living quarters will be using for the hot water to flow. The cold water will first have to go through this type of hot water calorifier where the water will be heated and then will be transfer out as hot water to the piping system.

CHAPTER 4

INITIAL RESULTS AND DISCUSSIONS

4.1 Decision Matrix

4.1.1 <u>Decision Matrix for pipes material between copper and plastic</u>

For this choice of selection betweens copper and plastic, this project used:
A rating scale of 1, 2,3,4,5 which means 1 = little to 5 = great effects to the project
A baseline of 1, 2, 3, 4, 5 (five point scale) for each criteria each higher point depends on its effectiveness towards the criteria

Table 4.1: Decision Matrix for pipes material

Criteria	Rating Scale	Plastic	Copper
Lower cost	5	5*5 = 25	3*5 = 15
Ease of installation	3	5*3 = 15	4*3 = 12
High pressure resistance	4	5*4 = 20	3*4 = 12
Resistant to flame	1	2*1 = 2	5*1 = 5
Life expectancy	3	3*3 = 9	5*3 = 15
Ease of manhandling	3	5*3 = 15	3*3 = 9
Corrosion resistance	1	3*1 = 3	5*1 = 5
Low friction loss	3	3*3 = 9	5*3 = 15
Space saving	3	4*3 = 12	5*3 = 15
Non conducive, will not rust	5	5*5 = 25	3*5 = 15
Less noisy	5	4*5 = 20	3*5 = 15
Self-insulating	5	5*5 = 25	3*5 = 15
	Total	180	148

From the decision matrix, the total point for plastic is 180 is higher compared to 158 of copper. So it is decided to use CPVC pipes for this project as it meet most of the criteria well. For CPVC pipes, this project refers to the pipes that are manufactured by FlowGuard Gold. All the specifications, sizes and flow rate data can be referred to the FlowGuard Gold, Pipe and Fittings, Design and Installation Manual for Water Distribution System. These references are acceptable and reliable because the pipe and fittings are produced to meet the standard requirement which is ASTM D2846. ASTM D2846 is Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Hot- and Cold-Water Distribution Systems.

4.1.2 Decision Matrix for hot water calorifier

For this choice of selection betweens hot water calorifer, this project used:
A rating scale of 1, 2,3,4,5 which means 1 = little to 5 = great effects to the project
A baseline of 1, 2, 3, 4, 5 (five point scale) for each criteria each higher point depends on its effectiveness towards the criteria

Table 4.2: Type of calorifer

Model	**Floor-standing calorifier SEM-1**	**Double calorifier SED-750/ 250**	**Intermediate calorifier SPU-2-W/ SPU2**
Cylinder capacity (ltr.)	Min. 300; Max. 1000	750	Min. 480; Max. 1520
Max. operating temperature, hot water/ heating water (°C)	95/110	95/95	95/110
Max. operating pressure (bar)	10/10*	10/3*	10/3*
Heat exchanger area (m^2)	Min. 0.95; Max. 1.45* Min. 1.4; Max. 2.4**	2.5	Min. 1.8; Max. 3.6***
Overall height (mm)	Min. 1755; Max. 2180	2050	Min. 1640; Max. 2150
Diameter (mm)	Min. 600; Max. 940	950	Min. 850; Max. 1200
Weight (kg)	Min. 130; Max. 350	250	Min. 85; Max. 230

Criteria	Rating Scale	SEM	SED	SPU
Lower cost	5	5*5 = 25	4*5 = 20	3*5 = 15
Ease of installation	3	5*3 = 15	4*3 = 12	4*3 = 12
High pressure resistance	4	5*4 = 20	3*4 = 12	3*4 = 12
Low primary requirement	4	4*4 = 16	3*4 = 12	5*4 = 20
Life expectancy	3	5*3 = 15	5*3 = 14	5*3 = 15
Reliability	5	5*5 = 25	3*5 = 15	4*5 = 20
Heat loss	5	5*3 = 15	5*4 = 20	5*5 = 25
Materials	3	4*3 = 12	4*3 = 12	4*3 = 12
Space saving	3	5*3 = 15	3*3 = 9	5*3 = 15
Heat exchanger	5	5*5 = 25	5*5 = 25	5*5 = 25
	Total	183	151	171

From the decision matrix, the total point for SEM is 183 is highest compared to 151 and 171 of SED and SPU respectively. So it is decided to use SEM calorifier which is a floor standing calorifer type for this project as it meet most of the criteria well. The data is referred to these references because these references are acceptable and reliable because the calorifiers are produced to meet the standard requirement which is stated before.

4.2 Loading Units Calculations (LU)

Loading Units are factor which take into account the flow rate at the appliance and the length in use. The number of each type of appliance, fed by the length of pipe being considered, shall be multiplied by the loading units as given in Table D.1 in Appendix C. Using Figure D.1 in Appendix C the number of LU can be converted into the total simultaneous demand for the pipe in liters per second. In this calculation, the LU is presented into two parts, one part for the potable cold water system and the other part is for the potable hot water system.

For example from living quarters at level 4, from the drawing of level 4 (roof level) in Appendix F, the total shower in the floor is two. Referring to Table D.1, looking at type of appliances, the loading units for shower is known to be three, since the quantity of the shower is two, the multiplication from this two will lead to the total loading units. This method also been used to other appliances such as basin, sink, tap and etc, but must first be referred to the drawing if there are any. From the total loading unit, the design flow rate is in liters per second (l/s) can be known by referring to Figure D.1. The flow rate obtained can be converted to gallon per minute (gpm) by multiply it with 15.85. This can be proved by the conversion below.

1 liter = 0.2642 gal

1 min = 60 seconds

1 litter/second = (1 liter) (0.2642 gal/liter) / (1second) (1min/ 60seconds)

= 15.85 gal/min

So, for living quarters at level 4,

Total shower = 2

Total basin = 2

Based on Table D.1, loading units for shower is 3 and loading unit for basin is 1.5 (for safety precautions, the lowest data is taken since the loading unit for basin is between 1.5 and 3. Multiplying this two data, the loading units are:

Shower = (3) (2)

= 6

Basin = (2) (1.5)

= 3

Total loading units = 6 + 3

= 9

Based on Figure D.1, when the loading units is 9, the design flow rate is approximately equal to 0.3 l/s. converting this to gpm,

Design flow rate = (0.3) (15.85)

= 4.755 gpm

The reason the data is converted from liter/second to gal/min is because the reference to use based on the FlowGuard Gold pipe reference is in gal/min.

The method above is used for every floor for both hot and cold water system.

4.2.1 Loading Units Summary for the Hot Water System

a) Living Quarters – Fourth Level

Hot Water Fixtures	**Fitting Quantity**	**Loading Unit (LU)**
Shower (sh)	2	6
Basin (b)	2	3
	Total	9

b) Living Quarters – Third Level

Hot Water Fixtures	**Fitting Quantity**	**Loading Unit (LU)**
Shower (sh)	11	33
Basin (b)	11	16.5
Sink (Janitor Store)	1	5
	Total	54.5

c) Living Quarters – Second Level

Hot Water Fixtures	Fitting Quantity	Loading Unit (LU)
Shower (sh)	5	15
Basin (b)	5	7.5
Tap (Ablution)	2	6
Sink (Janitor Store)	1	5
	Total	33.5

d) Living Quarters – First Level

Hot Water Fixtures	Fitting Quantity	Loading Unit (LU)
Basin (b)	4	6
Laundry / Linen	2	6
Sink (Laundry/Linen)	1	5
Sink (Janitor Store)	1	5
Sink (Galley)	3	15
	Total	37

4.2.2 Loading Units Summary for the Cold Water System

a) Living Quarters – Fourth Level

Cold Water Fixtures	Fitting Quantity	Loading Unit (LU)
Shower (sh)	2	6
Basin (b)	2	3
Tap (wc)	2	6
Urinal (u)	2	3
	Total	18

b) Living Quarters – Third Level

Cold Water Fixtures	Fitting Quantity	Loading Unit (LU)
Shower (sh)	11	33
Basin (b)	11	16.5
Sink (Linen)	1	5
Tap (wc)	11	16.5
	Total	71

c) Living Quarters – Second Level

Cold Water Fixtures	Fitting Quantity	Loading Unit (LU)
Shower (sh)	5	15
Basin (b)	5	7.5
Tap (wc)	5	7.5
Tap (Ablution)	2	6
Sink (Linen)	1	5
	Total	41

d) Living Quarters – First Level

Cold Water Fixtures	Fitting Quantity	Loading Unit (LU)
Urinal (u)	2	3
Basin (b)	4	6
Laundry / Linen	2	6
Sink (Laundry/Linen	1	5
Sink (Janitor Store)	1	5
Sink (Galley)	3	15
		40

From the data of the loading units, sizing of CPVC pipe will be using the FlowGuard Gold system. FlowGuard Gold system will use the same size pipe that a copper system would for a typical residential installation. A FlowGuard Gold system, unlike system utilizing insert fittings for joining the pipe, offers full-bore flow. This result is significantly reduced head loss.

4.3 Estimation of Design Velocity

The process of establishing a limiting or maximum flow velocity that is applicable to any piping material is not well defined. CPVC pipe systems revealed that velocities of 7 to 17 feet per second could be developed under maximum flow conditions.

A maximum design velocity of 10 feet per second is typically utilized for both hot and cold water CPVC system (½" and 2"). This design velocity is based on both field experience and laboratory investigation. The system should design and installed good engineering practice. It is recommended to have quick closing valves on the smaller branch lines when the velocity exceeds 5 ft/sec to avoid water hammer. Closing valves of 2" and 4" are not recommended for this case since the pipe is large and to close the valves will take a long time.

4.3.1 Early Estimation of Design Velocity for Hot Water System

For the hot water system, from plumbing fittings appliances and conversion to Loading Unit, it is summarized that the hot water demands is as follows:

The required potable hot water demand is, the total loading unit from first level to fourth level which is,

9 + 54.5 + 33.5 + 37 = 134 LU

From Figure D.1 in Appendix C, the required flow rate is 1.55 l/s or 24.57 US gpm at worst case scenario.

25.57 gpm = 3.28 ft^3/min

For the hot water main riser pipe header for the hot water services and using 2"NB as maximum size pipe diameter, from FlowGuard Gold guide, the pipe size of ½" and 2" is for velocity 10 ft/s or less.

As in Appendix B under Design Velocity section, the pipes and fittings shall be sized so that the maximum velocity that happens at the smallest pipe diameter should not exceed 10 feet per second (this is only valid for CPVC pipe usage), by substituting:

A = cross sectional area

ID = inside diameter

From FlowGuard Gold, ID of 2" pipe is 1.739

$$
\begin{aligned}
A &= (ID)^2 (\pi/4) \\
&= (1.739)^2 (\pi/4) \\
&= 2.375 \text{ inch}^2 \\
&= (2.375 \text{ inch}^2)(1 \text{ ft}^2/144 \text{ inch}^2) \\
&= 0.0165 \text{ ft}^2
\end{aligned}
$$

$$
\begin{aligned}
V &= Q/A \\
&= (3.28 \text{ ft}^3/\text{min}) / (0.0165 \text{ ft}^2) \\
&= 198.86 \text{ ft/min} \\
&= 3.314 \text{ ft/s}
\end{aligned}
$$

From the above calculations, and from the FlowGuard Gold reference of using CPVC pipe, the data concludes that the selected 2" NB diameter CPVC tube is acceptable for both services during maximum peak hour usage as the design follow the FlowGuard Gold guide.

4.3.2 Early Estimation of Design Velocity for Cold Water System

For the cold water system, from plumbing fittings appliances and conversion to Loading Unit, it is summarized that the cold water demands is as follows:

The required potable cold water demand is, the total loading unit from first level to fourth level which is,

18 + 71 + 41 + 40 = 170 LU

From Figure D.1 in Appendix C, the required flow rate is 1.81 l/s or 28.53 US gpm at worst case scenario.

28.53 gpm = 3.80 ft^3/min

For the cold water main riser pipe header for the hot water services and using 2"NB as maximum size pipe diameter, from FlowGuard Gold guide, the pipe size of ½" and 2" is for velocity 10 ft/s or less.

As in Appendix B under Design Velocity section, the pipes and fittings shall be sized so that the maximum velocity that happens at the smallest pipe diameter should not exceed 10 feet per second (this is only valid for CPVC pipe usage), by substituting:

A = cross sectional area

ID = outside diameter

From FlowGuard Gold, ID of 2" pipe is 1.739

$$
\begin{aligned}
A &= (ID)^2 (\pi/4) \\
&= (1.739)^2 (\pi/4) \\
&= 2.375 \text{ inch}^2 \\
&= (2.375 \text{ inch}^2)(1 \text{ ft}^2/144 \text{ inch}^2) \\
&= 0.0165 \text{ ft}^2 \\
V &= Q/A \\
&= (3.80 \text{ ft}^3/\text{min}) / (0.0165 \text{ ft}^2) \\
&= 230.30 \text{ ft/min} \\
&= 3.84 \text{ ft/s}
\end{aligned}
$$

From the above calculations, and from the FlowGuard Gold reference of using CPVC pipe, the data concludes that the selected 2" NB diameter CPVC tube is acceptable for both services during maximum peak hour usage as the design follow the FlowGuard Gold guide.

4.4 Friction Loss and Head Loss Calculation Through Straight Pipes and Fittings

The flow characteristics of water flowing through piping systems are affected by several factors including system configuration, pipe size and length, friction at the pipe and fitting surfaces. These and others factors cause a reduction in pressure (head-loss or pressure drop) over the length of the system. The following formula was used to calculate water velocities, head-losses and pressure drop as a function of flow rates. The results can be seen in the Appendix D. The Hazen-William formula can be used adequately describes these losses:

Head loses formula,

$H_L = 0.2083\ (100/C)^{1.852}\ (F_R^{1.852}/d_I^{4.8655})$

Where,

H_L	= Frictional head loss (feet of water per 100 feet)
C	= Hazen-William factor (150 for CPVC)
d_I	= Inside diameter of pipe (inches)
F_R	= Flow rate (gallon per minute)

Since the FlowGuard Gold guide has already tabulated the data for each flow rate, the calculations for each flow rate can be done by referring to Table 7 and Table 8 in Appendix D.

In addition to head losses that result from frictional forces in the pipe, losses also occur when water flows through valves, fittings, etc. in the system. These losses are difficult to calculate due to complex internal configuration of the fittings. Generally, loss values are determined for each fitting configuration by experimental tests and are expressed in equivalent length of strength pipe. The friction loss of valves and fittings can be referred to Table 15 in Appendix D.

4.4.1 <u>Cold Water System</u>

For each level, the route to the furthest fixture is the most highest with friction loss. Thus, the required static head needed at the initial point is calculated from the furthest fixture backward to the up stream point of the pressure control valve.

Figure 9: Cold water piping route for first floor

From Figure 9 which is showing Cold water piping route for first floor, the loading unit can be determined. From loading unit, using Figure D.1 in Appendix C, the number of LU can be converted into the total simultaneous demand for the pipe in l/s. The flow rates than can be multiply with 15.85 to convert flow rate form l/s to gal/min since the Table 7 in Appendix D from FlowGuard Gold is in gal/min. By know the design flow rate; the size of the pipe can be known using the table of Pipe Sizes for domestic cold and hot water service from Appendix C. Using the pipe sizes and flow rate that known, refer to the Table 7 in Appendix D to get the head loss per 100 feet for that size of the pipe. From the piping route, the length of the pipe from node to node can be known, so the total loss of pipe can be known by multiplying the length of the pipe with the head loss, but since the data from Table 7 in Appendix D is per 100 feet, the solution must be divided with 100. From Figure 9, the fittings can also be seen, referring to Table 15 from FlowGuard Gold in Appendix D the friction loss from each fitting from node to node can also be calculated. The total fittings must also be multiplying with the head loss earlier and be divided by 100. The total head loss from one node to another is the addition of those two solutions earlier. The head loss from the next node to another node can be found using the same method. After all the head loss from each node is known, the total head loss for the whole floor can be determined by adding all of them. The total head loss needed for the plumbing system to function efficiently must be added with the furthest equipment on that floor.

The calculation for cold water piping route for level 1 is summarized in Table 4.3.

Table 4.3: Head Loss Determination for cold water piping system for level 1

1	2	3	4	5	6	7 (5*6/100)	8	9 (7+8*6/100)
Nodes to Nodes	**No. Of LU**	**Design Flow Rates in gpm**	**Pipe Nominal Bore (in)**	**Actual Length of Pipe in ft.**	**Head loss per 100 feet**	**Total loss of pipe**	**Head loss in equivalent length of pipe in feet (from fittings)**	**Total head loss**
LEVEL 1								
From equipment to 100	5	4.76	¾	7.63	9.91	0.756	2E + 1GV = 2.75	1.03

100 - 105	5	4.76	1	20.62	2.89	0.596	5E + 1T_T = 8.75	0.85
105 - 110	8	4.76	1	2.71	2.89	0.078	1T_T = 1.75	0.13
110 – 115	11	5.04	1¼	18.37	3.94	0.724	3E + 1T_T = 7.82	1.03
115 – 120	20	7.13	1¼	27.53	3.94	1.085	1T_T = 2.30	1.18
120 – 125	25	7.75	1½	12.22	1.75	0.214	1T_T = 2.68	0.26
125 – 130	35	9.05	1½	10.28	1.75	0.180	1T_T = 2.68	0.23
130 - 135	40	9.83	1½	17.35	1.75	0.304	6E + 2T_T + 2GV + 1PCV = 21.1	0.67

1 psi can push water 2.31 ft.

For level 1, the furthest distance is from the Laundry / Linen room 107 (sink) that need 12 psi to operate.

Total head loss in friction for level 1 = 1.03 + 0.85 + 0.13 +1.03 +1.18 + 0.26 + 0.23 + 0.67

= 5.38 ft or 2.33 psi

Total psi for sink to operate = 2.33 + 12 psi

= 14.33 psi

The same method is used for the second, third and fourth floor of the cold water system.

Table 4.4: Pressure Needed for Each floor for Cold Water System

LEVEL	Pressure (psi)
Level 1	14.33
Level 2	46.99
Level 3	47.89
Level 4	46.97

Detailed calculations for each floor can be referred to Appendix G

4.4.2 Hot Water System

For each level, the route to the furthest fixture is the route with highest friction loss. Thus, the required static head needed at the initial point is calculated from the furthest fixture backward to the up stream point of the pressure control valve.

Figure 10: Hot water piping route for first floor

From Figure 10, Hot water piping route for first floor, the loading unit can be determined. From loading unit, using Figure D.1 in Appendix C, the number of LU can be converted into the total simultaneous demand for the pipe in l/s. The flow rates than can be multiply with 15.85 to convert flow rate form l/s to gal/min since the Table 7 in Appendix D from FlowGuard Gold is in gal/min. By know the design flow rate; the size of the pipe can be known using the table of Pipe Sizes for domestic cold and hot water service from Appendix C. Using the pipe sizes and flow rate that known, refer to the Table 7 in Appendix D to get the head loss per 100 feet for that size of the pipe. From the piping route, the length of the pipe from node to node can be known, so the total loss of pipe can be known by multiplying the length of the pipe with the head loss, but since the data from Table 7 in Appendix D is per 100 feet, the solution must be divided with 100. From Figure 10, the fittings can also be seen, referring to Table 15 from FlowGuard Gold in Appendix D the friction loss from each fitting from node to node can also be calculated. The total fittings must also be multiplying with the head loss earlier and be divided by 100. The total head loss from one node to another is the addition of those two solutions earlier. The head loss from the next node to another node can be found using the same method. After all the head loss from each node is known, the total head loss for the whole floor can be determined by adding all of them. The total head loss needed for the plumbing system to function efficiently must be added with the furthest equipment on that floor.

The calculation for cold water piping route for level 1 is summarized in Table 4.5

Table 4.5: Head Loss Determination for Hot water piping system for level 1

1	2	3	4	5	6	7 (5*6/100)	8	9 (7+8*6/100)
Nodes to Nodes	**No. Of LU**	**Design Flow Rates in GPM**	**Pipe Nominal Bore (in)**	**Actual Length of Pipe in Ft.**	**Head loss per 100 feet**	**Total loss of pipe**	**Head loss in equivalent length of pipe in feet (from fittings)**	**Total head loss**
LEVEL 1								

From equipment	5	4.76	¾	12.39	9.91	1.228	2E + 1GV = 2.75	1.50
100B – 105B	5	4.76	¾	18.91	9.91	1.874	$4E + 1T_B + 1T_T = 9.89$	2.85
105B – 110B	8	4.76	¾	2.71	9.91	0.269	$1T_T = 1.37$	0.40
110B – 115B	11	5.04	1	9.53	4.05	0.386	2E = 2.80	0.50
115B – 120B	11	5.04	1	7.57	4.05	0.307	$1E + 2T_T = 4.90$	0.51
120B – 125B	17	6.34	1¼	28.44	3.94	1.121	$1T_T = 2.30$	1.21
125B – 130B	22	7.40	1¼	14.82	3.94	0.584	$4E + 1T_T = 9.66$	0.96
130B – 135B	32	8.52	1½	10.44	1.75	0.183	$1T_T = 2.68$	0.23
135B – 140B	37	9.51	1½	20.26	1.75	0.355	$6E + 2T_T + 2GV + PCV = 21.1$	0.72

1 psi can push water 2.31 ft.

For level 1, the furthest distance is from the Laundry/Linen room 107 (sink) that need 12 psi to operate.

Total head loss for level 1 = 1.50 + 2.85 + 0.40 + 050 + 0.51 + 1.21 + 0.96 + 0.23 + 0.72

= 8.88 ft or 3.84 psi

Total psi for sink to operate = 3.84 + 12

= <u>15.84 psi</u>

The same method is used for the second, third, fourth floor and fourth floor (from cold water system back to hot water) of the hot water system

Table 4.6: Pressure Needed for Each floor for Hot Water System

LEVEL	Pressure (psi)
Level 1	15.84
Level 2	13.86
Level 3	14.65
Level 4	14.50
Level 4 (from cold water system back to hot water)	1.81

Detailed calculations for each floor can be referred to Appendix G

4.4.3 Results using Different Valves for Water Closets System

Using the same method from calculating the head loss from each floor, the water closets valve from each floor is changed and the new pressure head loss is determined. The pressure from each valve is change from 45 psi of flush valve to 30 psi for pressure-assisted flush tank and 10 psi for gravity flush tank.

Cold water for Pressure-Assisted Flush tank,
1 psi can push water 2.31 ft.
For level 2, the furthest distance is from the WC 209 (flush valve) that needs 30 psi to operate.

Total head loss in friction for level 2 = 1.2 + 0.88 + 0.63 + 0.16 + 0.53 + 0.09 + 1.11
= 4.6 ft or 1.99 psi

Total psi for pressure assisted tank to operate = 1.99 + 30
= 31.99 psi

The same method is used for each floor but do take note, that the changes of flush valve will not have any effect for hot water system since the water closets flushing system doesn't need hot water to function efficiently since there is no point of flushing the water closets with hot water.

The new pressure for each floor,

LEVEL	Pressure (psi)
Level 1	14.33
Level 2	31.99
Level 3	32.89
Level 4	31.97

The same methods are repeated to find the new pressure if the flush tank valve is change to gravity tank of 10 psi to function. The new pressure for each floor using the gravity flush tank,

LEVEL	Pressure (psi)
Level 1	14.33
Level 2	11.99
Level 3	12.89
Level 4	11.97

Detailed calculations for each floor can be referred to Appendix G

4.2 Heat Loss And Hot Water Return Water

4.2.1 Pipe Convective Heat Loss

Convection-cooling can sometimes be described by Newton's law of cooling in cases where the heat transfer coefficient is independent or relatively independent of the temperature difference between object and environment. The rate of heat transfer in such circumstances is derived below:

Newton's cooling law is a solution of the differential equation given by Fourier's law:

$Q = -h \cdot A \cdot (T_2 - T_1)$

Where:

Q = rate of heat flow, Btu/hr

A = the surface area of the heat being transferred, ft^2

h = coefficient of heat transfer, BTU/hr-ft^2-°F

$T_2 - T_1$ = temperature gradient, °F [17]

Input Information

Temperature of water CPVC pipe	140 °F or 60 °C
Temperature Ambient Air	70 °F or 21°C
Heat Transfer Coefficient (for air) [17]	15 W/m^2-K^1 or 2.643421 BTU/hr-ft^2-°F

Using Flow Guard Gold Pipe and Fittings Manual, the pipe dimension and weights can be known. Based on ASTM D 2846 in the Table 4 from Appendix E,

For ½ inch pipe, outside diameter OD = 0.625 inch

= 0.625/ 12

= 0.0521 feet

$A = \pi (OD) L$

Looking for the convective heat loss of the pipe per foot run, so length of the pipe is 1ft

So $A = \pi (0.0521 \text{ ft}) (1 \text{ ft})$

$= 0.1636 \text{ ft}^2$

So A $= \pi$ (0.0521 ft) (1 ft)

$= 0.1636\ ft^2$

T_2 $= 21\ ^oC$

$= 70\ ^oF$

T_1 $= 60\ ^oC$

$= 140\ ^oF$

Q $= -h\ (A)\ (T_2 - T_1)$

$= (-2.643421\ BTU/hr\text{-}ft^2\text{-}^oF\text{-}in)\ (0.0.1636\ ft^2)\ (70\ ^oF - 140\ ^oF)$

$= 30.27$ BTU/hr

These methods above are used for ¾", 1", 1 ¼", 1 ½" and 2" pipe and the detailed calculations can be refer to Appendix G

Heat loss from each CPVC pipe is shown below.

Table 4.7: Heat Loss per foot of pipe

Nominal bore		Heat loss for fluid inside pipe (Btu/hr.ft)
(mm)	(inches)	ΔT = (Temperature Ambient air to Temperature of water in pipes) (70 °F - 140 °F)
15	1/2	30.27
20	3/4	42.38
25	1	54.88
32	1 1/4	66.61
40	1 1/2	78.72
50	2	102.94

4.2.2 Hot Water Return Piping System Recirculation Sizing

Hot water return line summary:

From the piping diagram (AUTOCAD drawing, the length of each pipe from each floor can be known). Detailed drawing can be referred to Appendix F.

Table 4.8 (a): Total runs of pipe at Level 1

LEVEL 1			
PIPE SIZE (Ø)	HORIZONTAL PIPE (ft)	VERTICAL PIPE (ft)	TOTAL RUNS OF PIPE PER SIZE (ft)
¾" (20 mm)	34.01	0	34.01
1" (25 mm)	17.1	0	17.1
1 ¼" (32 mm)	73.96	0	73.96
Total runs of pipe per floor			125.07

Table 4.8 (b): Total runs of pipe at Level 2

LEVEL 2			
PIPE SIZE (Ø)	HORIZONTAL PIPE (ft)	VERTICAL PIPE (ft)	TOTAL RUNS OF PIPE PER SIZE (ft)
1" (25 mm)	23.61	0	23.61
1 ¼" (32 mm)	14.63	0	14.63
1 ½" (40 mm)	44.13	13.45	57.58
Total runs of pipe per floor			95.82

Table 4.8 (c): Total runs of pipe at Level 3

LEVEL 3			
PIPE SIZE (Ø)	HORIZONTAL PIPE (ft)	VERTICAL PIPE (ft)	TOTAL RUNS OF PIPE PER SIZE (ft)
1" (25 mm)	23.61	0	23.61
1 ¼" (32 mm)	27.1	0	27.1
1 ½" (40 mm)	32.94	13.45	46.39
Total runs of pipe per floor			97.1

Table 4.8 (d): Total runs of pipe at Level 4

LEVEL 4			
PIPE SIZE (Ø)	HORIZONTAL PIPE (ft)	VERTICAL PIPE (ft)	TOTAL RUNS OF PIPE PER SIZE (ft)
¾" (20 mm)	2.15	0	21.50
1" (25 mm)	13.55	0	13.55
2" (50 mm)	84.84	13.21	98.05
Total runs of pipe per floor			133.1

Table 4.8 (e): Total runs of pipe at Level 4 (cold water system back to hot water)

LEVEL 4 (from cold water system back to hot water)			
PIPE SIZE (Ø)	HORIZONTAL PIPE (ft)	VERTICAL PIPE (ft)	TOTAL RUNS OF PIPE PER SIZE (ft)
1" (25 mm)	4.81	0	4.81
2" (50 mm)	119.75	13.21	132.96
Total runs of pipe per floor			137.77

<u>Heat Loss can be found by multiplying the total runs of pipe from each floor with the heat loss per foot.</u>

Table 4.9 (a): Pipe heat loss for Level 1

LEVEL 1	
PIPE SIZE (Ø)	HEAT LOSS = HEAT LOSS PER FOOT (BTU/hr-ft) * TOTAL RUNS OF PIPE(ft)
¾" (20 mm)	(42.38) * (34.01) = 1441.34
1" (25 mm)	(54.59) * (17.10) = 933.49
1 ¼" (32 mm)	(66.61) * (73.96) = 4926.48
TOTAL HEAT LOSS (BTU/hr)	7301.31

Table 4.9 (b): Pipe heat loss for Level 2

LEVEL 2	
PIPE SIZE (Ø)	HEAT LOSS = HEAT LOSS PER FOOT (BTU/hr-ft) * TOTAL RUNS OF PIPE(ft)
1" (25 mm)	(54.59) * (23.61) = 1288.87
1 ¼" (32 mm)	(66.61) * (14.63) = 974.50
1 ½" (40 mm)	(78.72) * (57.58) = 4532.70
TOTAL HEAT LOSS (BTU/hr-ft)	6796.07

Table 4.9 (c): Pipe heat loss for Level 3

LEVEL 3	
PIPE SIZE (Ø)	HEAT LOSS = HEAT LOSS PER FOOT (BTU/hr-ft) * TOTAL RUNS OF PIPE(ft)
1" (25 mm)	(54.59) * (23.61) = 1288.87
1 ¼" (32 mm)	(66.61) * (27.1) = 1805.13
1 ½" (40 mm)	(78.72) * (46.39) = 3651.82
TOTAL HEAT LOSS (BTU/hr)	6745.82

Table 4.9 (d): Pipe heat loss for Level 4

LEVEL 4	
PIPE SIZE (Ø)	HEAT LOSS = HEAT LOSS PER FOOT (BTU/hr-ft) * TOTAL RUNS OF PIPE(ft)
¾" (20 mm)	(42.38) * (21.5) = 911.17
1" (25 mm)	(54.59) * (13.55) = 739.69
2" (50 mm)	(102.94) * (98.05) = 10093.27
TOTAL HEAT LOSS (BTU/hr-ft)	11744.13

Table 4.9 (e): Pipe heat loss for Level 4 (cold water system back to hot water)

LEVEL 4 (from cold water system back to hot water)	
PIPE SIZE (Ø)	HEAT LOSS = HEAT LOSS PER FOOT (BTU/hr-ft) * TOTAL RUNS OF PIPE(ft)
1" (25 mm)	(54.59) * (4.81) = 262.58
2" (50 mm)	(102.94) * (132.96) = 13686.90
TOTAL HEAT LOSS (BTU/hr-ft)	13949.48

$$\text{Hot re-circulating pump flow rate, gpm} = \frac{\text{system heat loss (Btu/h)}}{500 \times {}^{\circ}\text{F temperature drop}}$$

Table 4.10: Hot Re-circulating pump flow rate

LEVEL	FLOW RATE (gpm) = Heat Loss/ 500 * 27
Level 1	7301.31/ 500 * 27 = 0.541 gpm
Level 2	6796.07/ 500 * 27 = 0.503 gpm
Level 3	6745.82/ 500 * 27 = 0.500 gpm
Level 4	11744.13/ 500 * 27 = 0.870 gpm
Level 4 (from cold water system back to hot water)	13949.48/ 500 * 27 = 1.033 gpm

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Cold Water Plumbing System

From the cold water calculation, the furthest most fixture is located at roof of the living quarters Gymnasium toilet which is 46.97 psi + 23.19 psi (static lift) = 70.16 psi. This calculation also concludes that the minimum required flow at peak is 25.57 gal/min and the minimum required tie-in point is 75 psi to furthermost remote shower to be functional.

Since the pressure required at the tie-in below the living quarters is 75 psi, the pressure will be too great for other fixtures at lower level and therefore pressure control valves (PCV) is required.

The table below indicates the PCV setting required at respectively deck level to prevent over pressure and water hammer in the plumbing system.

Table 5.1: PCV requirement for different levels for cold water system

LEVEL	**Valve**	**AVAILABLE PRESSURE**	**PCV SETTING REQUIRED**
1	Check valve	75	14.33
2	Check valve	75	46.99
3	Check valve	75	47.89

5.2 Hot Water Plumbing System

From the hot water calculation, the furthest most fixture is located at roof of the living quarters Gymnasium toilet which is 14.56 psi + 23.15 psi (static lift) = 37.71 psi. This calculation also concludes that the minimum required flow at peak is 28.53 gal/min and the minimum required tie-in point is 40 psi to furthermost remote water closet to be functional.

Since the pressure required at the tie-in below the living quarters is 40 psi, the pressure will be too great for other fixtures at lower level and therefore pressure control valves (PCV) is required.

The table below indicates the PCV setting required at respectively deck level to prevent over pressure and water hammer in the plumbing system.

Table 5.2: PCV requirement for different levels for hot water system

LEVEL	Valve	AVAILABLE PRESSURE	PCV SETTING REQUIRED
1	Check valve	40	15.84
2	Check valve	40	13.86
3	Check valve	40	14.65

5.3 Recommendation

Based on the results from this project, the following are some recommendations to improve the project.

a) The location of the hot water calorifier can be reviewed and changed because the lower the level of the hot water calorifier is located, the lower the pressure is needed for the water to be pushed up.

b) In sizing hot water circulating systems, the greater the temperature drop across the system, the less water is required to be pumped through the system and, therefore, the greater the savings on pumping costs. So a different in the temperature drop can be tested and analysis and can be different accordingly.

c) Additional investigation can be done by varying material for the piping system . How different materials can affect the life span of the living quarters, including the costs that can be save, can be investigated.

REFERENCES

1) Slawsky, Richard, New Orleans City Business, April 11 2005, Deep water drilling increases need for offshore living quarters for oil and gas company workers
2) FEED<http://www.contractorsunlimited.co.uk/cgi-bin/glossitemsrch.pl?header=Term&method=all&search=FEED>, accessed on 1st of September 2010
3) Greg Palmer, CAD Design Basics For Engineering Students, 6 April 2010. < http://www.squidoo.com/CAD-Design-Basics>, accessed on 19th of August 2010
4) GMS Storage Calorifier, Thermal Product LTD, www.gmsthermal.co.uk
5) Solar calorifiers, Wolf GMBH Industries
6) Storage Calorifiers, Rycroft Heating the World's Water, Rycroft Ltd
7) A. Bhatia, CED Engineering, Design of Potable Water Plumbing System, Continuing Education and Development Inc
8) E. Nancy R. Tague, The Quality Toolbox, Second Edition, ASQ Quality Press, 2004, pages 219 – 223
9) CAD Software, 2009. < http://cadsoftware.us/>, accessed on 17th of August 2010
10) Haresh Khemani, Benefits of using the CAD Software, 1 December 2008. <http://www.brighthub.com/engineering/mechanical/articles/17593.aspx#ixzz0qVwI8ffA>, accessed on 19th of August 2010
11) Flowguard Gold and Corzan, Pipe and Fittings, Design and Installation Manual for Water Distribution System
12) ASTM D2846, Specification for Chorinated Poly(Vinyl Chloride)(CPVC) Plastic Hot and Cold Water Distribution System, America Society for Testing and Materials
13) Architectural Graphic Standard, Andy Pressman, American Institute of Architects, Smith Manan Architects

14) BS 6700:2006, British Standard that specifies requirements and gives recommendations for the design, installation, testing and maintenance of services supplying water for domestic use within building and their cartilages

15) ASME B31.3 Process Piping Guide, American Society of Mechanical Engineers Standard

16) Haig Demegian, PE, CPD, Dec 2007, PSDM, Recirculating Domestic Hot Water System, Continuing Education from Plumbing System and Design

17) Heat Transfer,Incropera, F.P., Dewitt, D.P. (2001). Introduction to Heat Transfer (4th ed.), John Wiley & Sons, New York

18) Fluid Mechanics, Cengel, Y.A., Cimbala, J.M. (2006). Fluid Mechanics Fundamentals and Applications (1st ed.), McGraw-Hill, New York

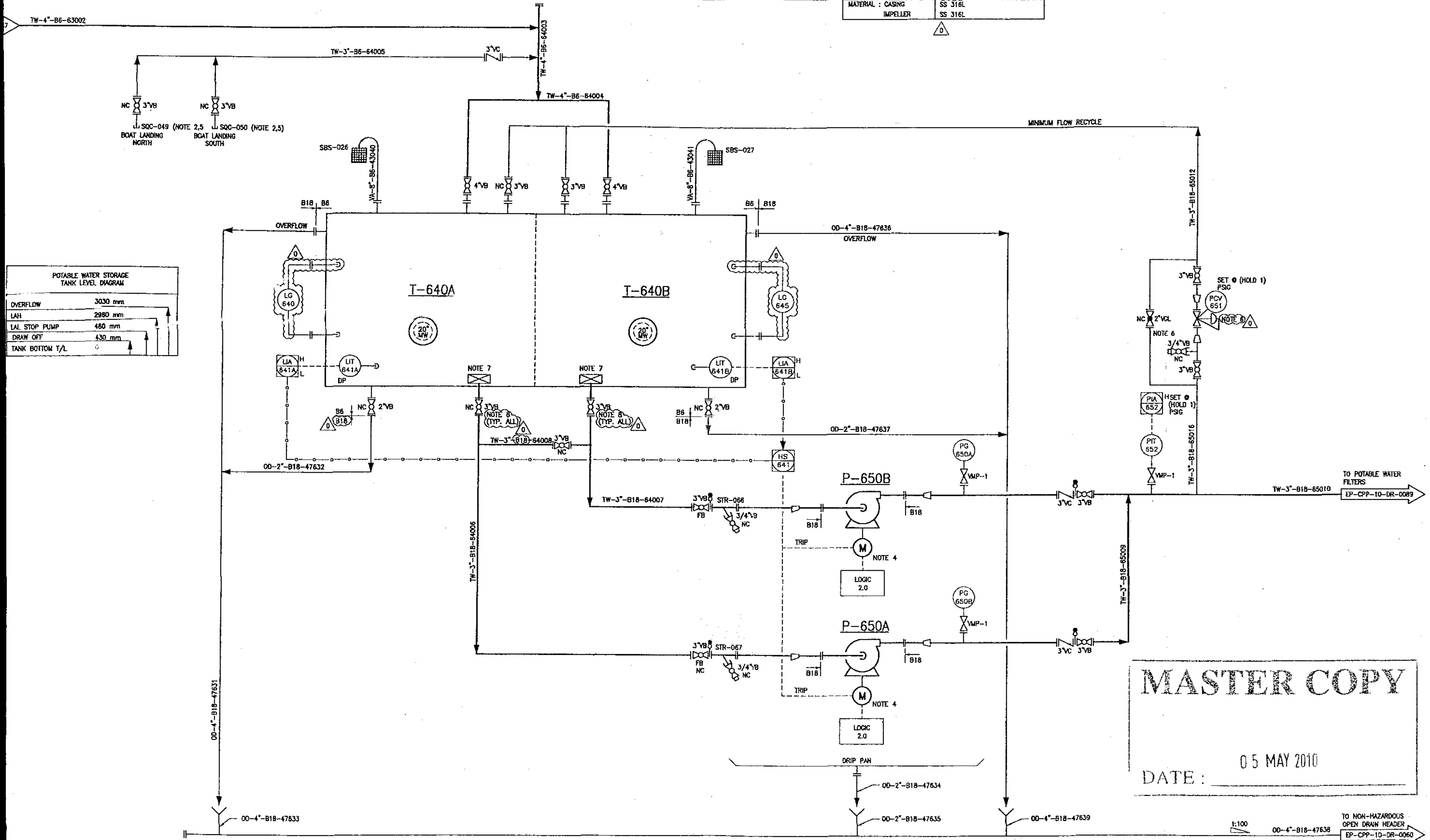
APPENDIX A

PIPING AND INSTRUMENTATION DIAGRAM FOR THE LOCATION OF THE WATER STORAGE TANK (T-640A AND T-640B)

T-640A/B (2x50% COMPARTMENT)	
SERVICE	POTABLE WATER STORAGE TANK
SIZE	6000m (L) x 4200m (W) x 3200m (H)
DESIGN PRES. (PSIG)	WATERFULL + 7/-0.03
DESIGN TEMP. (°F)	140
OPERATING PRESS. (PSIG)	ATM
OPERATING TEMP. (°F)	AMB
MATERIAL	SS 316L
TRIM NO.	B6

P-650A/B (2 x 100%)	
SERVICE	POTABLE/WASH WATER PUMP
DESIGN PRES. (PSIG)	205
DESIGN TEMP. (°F)	140
DISCHARGE PRESS. (PSIG)	145
OPERATING TEMP. (°F)	AMB
RATED CAPACITY (USGPM)	71
DIFFERENTIAL PRESS. (PSI)	145
ABSORBED POWER (kW)	(HOLD 1)
MATERIAL : CASING	SS 316L
IMPELLER	SS 316L

POTABLE WATER STORAGE TANK LEVEL DIAGRAM	
OVERFLOW	3030 mm
LAH	2980 mm
LAL STOP PUMP	460 mm
DRAW OFF	430 mm
TANK BOTTOM T/L	0



MASTER COPY

DATE : 05 MAY 2010

...B TO COVER ENTIRE RANGE.
... DECK.
...GE TANKS ARE PROVIDED FOR 7 DAYS STORAGE BASED ON ... LITRES/DAY/PERSON FOR 30 PEOPLE.
...BE CONNECTED TO THE EMERGENCY BUS.
... DISSIMILAR TO DIESEL COUPLING CONNECTION.
...ATER FOR 2 PUMPS RUNNING.

0	04.05.10	APPROVED FOR CONSTRUCTION (AFC)	SNS	TS	AHN	AA
A	26.03.10	ISSUED FOR APPROVAL (IFA)	RR	TS	AHN	AA
2A	25.02.10	ISSUED FOR HAZOP	RR	TS	AHN	AA
1A	08.02.10	INTER DISCIPLINE CHECK(IDC)/ISSUED FOR COMMENT(IFC)	SNS	TS	AHN	AA

NEWFIELD
NEWFIELD PENINSULA

AkerSolutions
AKER ENGINEERING MALAYSIA SDN.BHD.
Level 20, Menara HLA
No 3 Jalan Kia Peng

SCALE : NONE
DRAWN : -
DATE : -

PM329 EAST PIATU DEVELOPMENT PROJECT

PROJECT TITLE : DETAILED ENGINEERING DESIGN SERVICES

DRAWING TITLE : PIPING AND INSTRUMENT DIAGRAM

JOB NO. 103268

CONTRACT NO. C-NFX-PM323-P-8258

SHT. 1 OF 1

APPENDIX B
DESIGN VELOCITY DATA
&
HAZEN WILLIAM C FACTOR

ysical and Thermal Properties of ıwGuard Gold® CPVC

(Table 6)

Physical Properties Comparison

Property	CPVC	ASTM
Specific Gravity	1.55	D792
IZOD Impact Strength (ft. lbs./inch, notched)	3.0	D256A
Modulus of Elasticity, @ 73°F, psi	4.23×10^5	D638
Ultimate Tensile Strength, psi	8,400	D638
Compressive Strength, psi	9,600	D695
Poisson's Ratio	.35 - .38	-
Working Stress @ 73°F, psi	2,000	D1598
Hazen-Williams C Factor	150	-
Coefficient of Linear Expansion in./(in. °F)	3.4×10^{-5}	D696
Thermal Conductivity BTU/hr./ft.^{2}/°F/in.	0.95	C177
Limiting Oxygen Index	60%	D2863
Electrical Conductivity	Non Conductor	

lraulic Design

ng CPVC Pipe. A FlowGuard Gold® system will use same size pipe that a copper system would for a cal residential installation. For systems using larger s, design should be based on fixture demand rates. owGuard Gold® system, unlike systems utilizing insert ıgs for joining the pipe, offers full-bore flow. This lts in significantly reduced head loss.

ign Velocity. The process for establishing a limiting or imum flow velocity that is applicable to any piping erial is not well defined. For some materials, there may elocities that can create abrasion or erosion, but there) evidence that this occurs with CPVC piping under known operating conditions. An investigation of some C systems revealed that velocities of 7 to 17 feet per nd could be developed under maximum flow conditions.

ıximum design velocity of 10 feet per second is typically ed for both hot water and cold water CTS CPVC systems hrough 2") and for IPS CPVC hot and cold water ibution systems 4" and smaller. A design velocity of 5 per second is typically used for IPS CPVC water bution systems larger than 4". This design velocity is d on both field experience and laboratory investigation.

The CPVC design velocity is different from copper, which has a recommended maximum design velocity of 5 feet per second for hot water and 8 feet per second for cold water.

The system should be designed and installed utilizing good engineering practices. To avoid water hammer, quick closing valves are not recommended on 2" to 4" IPS water mains when the velocity exceeds 5 ft/sec. It is acceptable to have quick closing valves on the smaller branch lines.

Hazen-William C Factor. Hydraulic calculations for sizing of FlowGuard Gold® pipe and fittings should be calculated using a Hazen-William C Factor of 150. While both copper and CPVC use a C Factor of 150 for new systems, as copper ages, the ID of the pipe is subject to pitting and scaling causing pressure loss to increase over time. Since a FlowGuard Gold® system is not subject to pitting or scaling, the C Factor will remain constant as the system ages.

Head-Loss Characteristics - Pipe. The flow characteristics of water flowing through piping systems are affected by several factors including system configuration, pipe size and length, friction at the pipe and fitting surfaces, etc. These and other factors cause a reduction in pressure (head-loss, also expressed as pressure drop) over the length of the system. This section deals only with the head-losses that result from frictional forces in the various sizes of CPVC pipe and fittings.

The following formulas were used to calculate water velocities, head-losses and pressure drops as function of flow rates. The results are given in Tables 7 thru 10. Head-loss as a function of water velocity has also been calculated and can be found in Tables 11 thru 14.

The Hazen-William formula can be used to adequately describe these losses:

Head Loss Formula

$$H_L = 0.2083(100/C)^{1.852} \times F_R^{1.852}/d_i^{4.8655}$$

Velocity Formula

$$V_w = 0.4085F_R/d_i^2$$

Where:
- H_L = Frictional head loss (feet of water per 100 feet)
- C = Hazen-William factor (150 for CPVC)
- F_R = Flow rate (gal/min.)
- d_i = Inside diameter of pipe (inches)
- V_w = Velocity of water (feet/second)

One foot of water = 0.4335 psi

APPENDIX C

FIGURE D.1 – CONVERSION OF LOADING UNITS TO DESIGN FLOW RATE

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TABLE D.1 – LOADING UNITS FOR HOT OR COLD SUPPLY

Table 3 **Design flow rates**

Outlet fitting or appliance	Rate of flow l/s Design rate	Minimum rate
WC cistern (to fill in two minutes)	0.13	0.05
WC flushing trough (per WC served) (see Note 2)	0.15	0.10
Urinal cistern (each position served)	0.004	0.002
Washbasin	0.15	0.10
Handbasin (pillar taps)	0.10	0.07
Handbasin (spray or spray mixer taps)	0.05	0.03
Bidet	0.20	0.10
Bath (G ¾)	0.30	0.20
Bath (G 1)	0.60	0.40
Shower head (see Note 3)	0.20	0.10
Kitchen sink (G ½)	0.20	0.10
Kitchen sink (G ¾)	0.30	0.20
Kitchen sink (G 1)	0.60	0.40
Washing machine	0.20	0.15
Dish-washing machine (see Note 1)	0.15	0.10
Pressure flushing valves for WCs or urinals	1.5 max.	1.2 min.
Urinal flushing cistern	0.3 max.	0.15 min.

NOTE 1 The manufacturer should be consulted for required flow rates to washing and dish-washing machines for other than single dwellings.

NOTE 2 WC flushing troughs are recommended where anticipated use of WCs is more frequent than once per minute.

NOTE 3 The rate of flow required to shower heads will depend on the type fitted and the advice of the shower manufacturer should be sought.

5.6 Preservation of water quality

5.6.1 General

5.6.1.1 The installation shall be constructed so that water delivered shall not become contaminated or that contamination of the water supplier's mains does not occur.

*COMMENTARY AND RECOMMENDATIONS ON **5.6.1.1***

See WFRs [1], which cover the means for the prevention of backflow.

Water suppliers are duty bound to provide a supply of water for domestic purposes which is suitable and safe for drinking.

Table D.1 **Loading units – Hot or cold supply**

Type of appliance	**Loading units**
WC flushing cistern	2
Wash basin ½ – DN 15	1.5 to 3
Bath tap ¾ – DN 20	10
Bath tap 1 – DN 25	22
Shower	3
Sink tap ½ – DN 15	3
Sink tap ¾ – DN 20	5
Domestic clothes or dishwashing machines ½ – DN 15	3

NOTE 1 WC cisterns with either single or dual flush control have the same LU.

NOTE 2 The wash basin LU is for use where pillar taps are installed. The larger LU is applicable to situations such as schools and those offices where there is a peak period of use. Where spray taps are installed, an equivalent continuous demand of 0.04 l/s should be assumed.

NOTE 3 Urinal cistern demand is very low, and is normally disregarded.

NOTE 4 Outlet fittings for industrial purposes or requiring high peak demands, should be taken into account by adding 100% of their flow rate to the simultaneous demand for other appliances obtained by using LUs.

D.2 Pressure losses in pipes and fittings

D.2.1 Pipes and pipe fittings

Pressure, or head, losses due to resistance of pipes and fittings at various flows are published in the form of tables for pipes of different materials by the various pipe manufacturers organizations. A nomogram showing pressure losses and flows of water at a temperature of 10 °C through pipes, based on Lamont's smooth pipe formula S3, is shown in Figure D.2.

Typical values for equivalent pipe lengths for elbows and tees are shown in Table D.3.

D.2.2 Draw-off taps

The residual head available at each tap or outlet fitting should be at least equal to the loss of head through the tap at the design flow rate. Alternatively, the loss of head may be expressed as an equivalent length of pipe.

Some typical losses for low pressure taps are shown in Table D.2.

Fitting	litre/hr	gal/hr
Basin (private)	14	3
Basin (public)	45	10
Shower	180	40

Fitting	Consumption litre/hr	gal/hr
Sink	45–90	10–20
Bath	90–180	20–40

Hot water consumption per occupant

Type of building	*Consumption per occupant*		*Peak demand per occupant*		*Storage per occupant*	
	litre/day	*gal/day*	*litre/hr*	*gal/hr*	*litre*	*gal*
Factories (no process)	22–45	5–10	9	2	5	1
Hospitals, general	160	35	30	7	27	6
mental	110	25	22	5	27	6
Hostels	120	26	50	11	30	7
Hotels	130–230	28–50	50	11	30	7
Houses and flats	45–160	10–35	50	11	30	7
Offices	22	5	9	2	5	1
Schools, boarding	115	25	30	7	25	5
day	10	2	9	2	5	1

Contents of fittings

Fitting	*Contents*	
	litre	*gal*
Basin, normal	4	0.8
Basin, full	9	2
Sink, normal	18	4
Sink, full	30	6.5
Bath	100–135	22–30

Flow rates

Fitting	*Flow rate*	
	litre/s	*gal/min*
Basin	0.08	1
Sink	0.15	2
Bath	0.15	2
Shower	0.09–0.12	1.2–1.6

Toilet = 4 CW 2 HW

Maximum dead leg of hot water pipe without circulation

Pipe size		*Length*
Steel	*Copper*	*m*
15	15	12
20	22	8
25	28	3

Nominal bore of pipe			*Maximum number of draw offs served*		
			Flow pipes		
in	*Steel pipe mm*	*Copper pipe mm*	*Head up to 20 m (70 ft)*	*Head over 20 m (70 ft)*	*Return pipes*
$\frac{1}{2}$	15	15	1	1 to 2	1 to 8
$\frac{3}{4}$	20	22	2 to 4	3 to 9	9 to 29
1	25	28	5 to 8	10 to 19	30 to 66
$1\frac{1}{4}$	32	35	9 to 24	20 to 49	67 to 169
$1\frac{1}{2}$	40	42	25 to 49	50 to 79	170 to 350
2	50	54	50 to 99	80 to 153	—
$2\frac{1}{2}$	65	67	100 to 200	154 to 300	—

For the purpose of this table, basins, sinks, showers count as one draw off, baths count as two draw offs.

Cold water storage per occupant

Type of building	*Storage per occupant*	
	litres	*gal*
Factories (no process)	10	2
Hospitals per bed	150	33
per staff on duty	45	10
Hostels	90	20
Hotels	150	33
Houses and flats	135	30

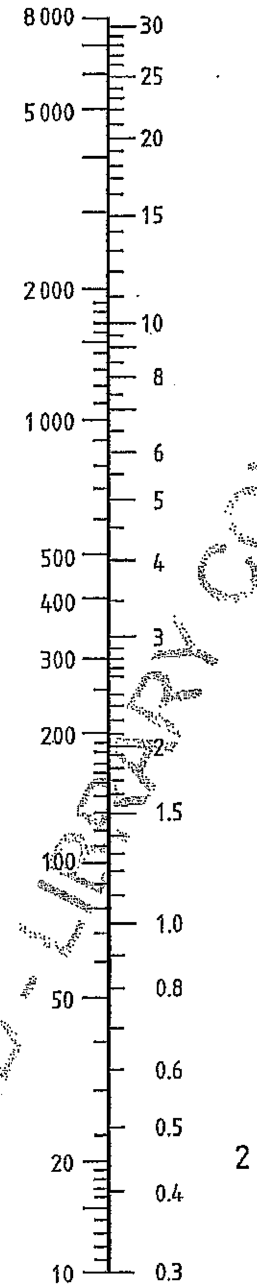
Type of building	*Storage per occupant*	
	litres	*gal*
Offices with canteen	45	10
without canteen	35	8
Restaurant, per meal	7	1.5
Schools		
boarding	90	20
day	30	7

Cold water storage per fitting

Type of fitting	*Storage per unit*	
	litres	*gal*
Shower	450–900	100–200
Bath	900	200
W.C.	180	40
Basin	90	20

Type of fitting	*Storage per unit*	
	litres	*gal*
Sink	90	20
Urinal	180	40
Garden watering tap	180	40

Figure D.1 **Conversion of loading units to design flow rate**



y
Loading units

2 Design flow rate, litres per second

APPENDIX D

TABLE 7 AND 8 – FRICTIONAL LOSSES AT DIFFERENT FLOW RATES

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TABLE 15 – FRICTION LOSS IN VALVES AND FITTINGS IN TERM OF EQUIVALENT LENGTH

(Table 7)

FlowGuard Gold® Pipe SDR 11 (ASTM D 2846)

Frictional Losses At Different Flow Rates

1/2"			3/4"			1"		
V_W	H_L	P_L	V_W	H_L	P_L	V_W	H_L	P_L
1.71	3.19	1.38	0.80	0.50	0.22	0.48	0.15	0.06
3.42	11.53	5.00	1.60	1.82	0.79	0.96	0.53	0.23
5.13	24.43	10.59	2.40	3.85	1.67	1.44	1.12	0.49
6.83	41.62	18.04	3.20	6.55	2.84	1.93	1.91	0.83
8.54	62.91	27.27	4.00	9.91	4.29	2.41	2.89	1.25
0.25	88.18	38.23	4.79	13.89	6.02	2.89	4.05	1.76
1.96	117.32	50.86	5.59	18.47	8.01	3.37	5.39	2.34
3.67	150.23	65.13	6.39	23.66	10.26	3.85	6.90	2.99
5.38	186.85	81.00	7.19	29.42	12.76	4.33	8.58	3.72
7.08	227.11	98.45	7.99	35.76	15.50	4.82	10.43	4.52
			11.99	75.78	32.85	7.22	22.11	9.58
			15.98	129.11	55.97	9.63	37.67	16.33
						12.04	56.94	24.69
						14.45	79.82	34.60
						16.86	106.19	46.03

(Table 9)

Corzan® Pipe Schedule 80 (ASTM F 441)

Frictional Losses At Different Flow Rates

Flow Rate GPM	2 1/2"			3"			4"		
	V_W	H_L	P_L	V_W	H_L	P_L	V_W	H_L	P_L
25	1.95	0.68	0.29	1.25	0.23	0.10	0.71	0.06	0.03
50	3.90	2.45	1.06	2.49	0.82	0.36	1.42	0.21	0.09
75	5.85	5.19	2.25	3.74	1.74	0.76	2.14	0.45	0.19
100	7.80	8.85	3.83	4.98	2.97	1.29	2.85	0.76	0.33
125	9.75	13.37	5.80	6.23	4.49	1.95	3.56	1.16	0.50
150	11.69	18.74	8.12	7.47	6.30	2.73	4.27	1.62	0.70
175	13.64	24.94	10.81	8.72	8.38	3.63	4.99	2.16	0.93
200	15.59	31.93	13.84	9.96	10.73	4.65	5.70	2.76	1.20
225	17.54	39.71	17.22	11.21	13.35	5.79	6.41	3.43	1.49
250				12.45	16.22	7.03	7.12	4.17	1.81
300				14.94	22.74	9.86	8.55	5.85	2.54
350				17.43	30.25	13.12	9.97	7.78	3.37
400							11.40	9.96	4.32
500							14.25	15.06	6.53
600							17.10	21.11	9.15

(Table 8)

FlowGuard Gold® Pipe SDR 11 (ASTM D 2846)

Frictional Losses At Different Flow Rates

1 1/4"			1 1/2"			2"		
Vw	H_L	P_L	Vw	H_L	P_L	Vw	H_L	P_L
1.61	1.09	0.47	1.16	0.49	0.21	0.68	0.13	0.06
3.23	3.94	1.71	2.31	1.75	0.76	1.35	0.49	0.21
4.84	8.35	3.62	3.47	3.71	1.61	2.03	1.03	0.45
6.46	14.23	6.17	4.63	6.33	2.74	2.70	1.76	0.76
8.07	21.51	9.33	5.78	9.56	4.15	3.38	2.66	1.15
9.68	30.15	13.07	6.94	13.40	5.81	4.05	3.73	1.62
1.30	40.11	17.39	8.09	17.83	7.73	4.73	4.96	2.15
2.91	51.37	22.27	9.25	22.83	9.90	5.40	6.35	2.75
4.52	63.89	27.70	10.41	28.40	12.31	6.08	7.89	3.42
6.14	77.66	33.66	11.56	34.52	14.96	6.75	9.60	4.16
7.75	92.65	40.16	12.72	41.18	17.85	7.43	11.45	4.96
			13.88	48.38	20.97	8.10	13.45	5.83
			16.19	64.37	27.90	9.46	17.89	7.76
						10.81	22.91	9.93
						12.16	28.50	12.35
						13.51	34.64	15.02
						16.89	52.37	22.70

(Table 10)

Corzan® Pipe Schedule 80 (ASTM F 441)

Frictional Losses At Different Flow Rates

Flow Rate GPM	6"			8"			10"		
	Vw	H_L	P_L	Vw	H_L	P_L	Vw	H_L	P_L
100	1.25	0.10	0.04	0.71	0.03	0.01	0.45	0.01	0.00
200	2.51	0.37	0.16	1.43	0.10	0.04	0.91	0.03	0.01
300	3.76	0.79	0.34	2.14	0.20	0.09	1.36	0.07	0.03
400	5.01	1.35	0.59	2.86	0.34	0.15	1.81	0.11	0.05
500	6.27	2.04	0.89	3.57	0.52	0.23	2.27	0.17	0.07
600	7.52	2.86	1.24	4.28	0.73	0.32	2.72	0.24	0.10
700	8.77	3.81	1.65	5.00	0.97	0.42	3.17	0.32	0.14
800	10.03	4.88	2.11	5.71	1.24	0.54	3.63	0.41	0.18
900	11.28	6.06	2.63	6.42	1.54	0.67	4.08	0.51	0.22
1000	12.53	7.37	3.20	7.14	1.87	0.81	4.53	0.62	0.27
1250	15.67	11.14	4.83	8.92	2.83	1.23	5.67	0.94	0.41
1500				10.71	3.97	1.72	6.80	1.32	0.57
1750				12.49	5.28	2.29	7.93	1.75	0.76
2000				14.28	6.76	2.93	9.07	2.24	0.97
2250				16.06	8.41	3.65	10.20	2.79	1.21
2500							11.33	3.39	1.47
3000							13.60	4.75	2.06
3500							15.87	6.32	2.74

V_W = Velocity of water (feet/second)
H_L = Frictional head loss (feet of water per 100 feet)
P_L = Pressure Loss (psi per 100 feet)

(Table 11)

FlowGuard Gold® Pipe
SDR 11 (ASTM D 2846)
Frictional Losses At Different Water Velocities

1/2"			3/4"			1"		
F_R	H_L	P_L	F_R	H_L	P_L	F_R	H_L	P_L
1.17	4.28	1.85	2.50	2.75	1.19	4.15	2.05	0.89
2.34	15.44	6.69	5.01	9.93	4.30	8.31	7.40	3.21
3.51	32.71	14.18	7.51	21.04	9.12	12.46	15.68	6.80
4.68	55.72	24.16	10.01	35.84	15.54	16.61	26.71	11.58
5.85	84.24	36.52	12.51	54.18	23.49	20.76	40.38	17.50

(Table 12)

FlowGuard Gold® Pipe
SDR 11 (ASTM D 2846)
Frictional Losses At Different Water Velocities

1 1/4"			1 1/2"			2"		
F_R	H_L	P_L	F_R	H_L	P_L	F_R	H_L	P_L
6.2	1.62	0.70	8.6	1.34	0.58	14.8	0.98	0.42
12.4	5.86	2.54	17.3	4.83	2.09	29.6	3.54	1.53
18.6	12.43	5.39	25.9	10.24	4.44	44.4	7.49	3.25
24.8	21.17	9.18	34.6	17.45	7.56	59.2	12.77	5.53
31.0	32.01	13.87	43.2	26.37	11.43	74.0	19.30	8.37

(Table 13)

Corzan® Pipe
Schedule 80 (ASTM F 441)
Frictional Losses At Different Water Velocities

2 1/2"			3"			4"		
F_R	H_L	P_L	F_R	H_L	P_L	F_R	H_L	P_L
26	0.71	0.31	40	0.55	0.24	70	0.40	0.17
51	2.57	1.11	80	1.98	0.86	140	1.43	0.62
77	5.45	2.36	120	4.20	1.82	211	3.04	1.32
103	9.28	4.02	161	7.15	3.10	281	5.17	2.24
128	14.03	6.08	201	10.81	4.69	351	7.82	3.39

(Table 14)

Corzan® Pipe
Schedule 80 (ASTM F 441)
Frictional Losses At Different Water Velocities

6"			8"			10"		
F_R	H_L	P_L	F_R	H_L	P_L	F_R	H_L	P_L
160	0.25	0.11	280	0.18	0.08	441	0.14	0.06
319	0.89	0.39	560	0.64	0.28	882	0.49	0.21
479	1.88	0.82	841	1.36	0.59	1323	1.04	0.45
638	3.21	1.39	1121	2.31	1.00	1764	1.78	0.77
798	4.85	2.10	1401	3.50	1.52	2206	2.69	1.17

= Velocity of water (feet/second)
: Flow Rate (gal/min.)
= Frictional head loss (feet of water per 100 feet)
: Pressure Loss (psi per 100 feet)

Head Loss Characteristics - Valves and Fittings. In addition to head losses that result from frictional forces in the pipe, losses also occur when water flows through valves, fittings, etc. in the system. These losses are difficult to calculate due to the complex internal configuration of the various fittings. Generally, loss values are determined for each fitting configuration by experimental tests and are expressed in equivalent length of straight pipe. Typical equivalent length values for valves and fittings can be found in Tables 15 and 16.

(Table 15)

Friction Loss in FlowGuard Gold® CTS Valves and Fittings in Terms of Equivalent Length (L) – Feet of Straight Pipe Note 1

Nominal Pipe Size	Gate Valve Full Open	Globe Valve Full Open	Angle Valve Full Open	Swing Check Valve Full Open	90° Elbow	Long Radius 90°or 45° Standard Elbow	Standard Tee Through Flow	Standard Flow Branch Flow
1/2"	0.41	17.6	7.78	5.18	1.55	0.83	1.04	3.11
3/4"	0.55	23.3	10.3	6.86	2.06	1.10	1.37	4.12
1"	0.70	29.7	13.1	8.74	2.62	1.40	1.75	5.25
1 1/4"	0.92	39.1	17.3	11.5	3.45	1.84	2.30	6.90
1 1/2"	1.07	45.6	20.1	13.4	4.03	2.15	2.68	8.05
2"	1.38	58.6	25.8	17.2	5.17	2.76	3.45	10.30

(Table 16)

Friction Loss in Corzan® IPS Valves and Fittings in Terms of Equivalent Length (L) – Feet of Straight Pipe Note 1

Nominal Pipe Size	Gate Valve Full Open	Globe Valve Full Open	Angle Valve Full Open	Swing Check Valve Full Open	90° Elbow	Long Radius 90°or 45° Standard Elbow	Standard Tee Through Flow	Standard Flow Branch Flow
2 1/2"	1.65	70.0	30.9	20.6	6.1	3.3	4.1	12.2
3"	2.04	86.9	38.4	25.5	7.6	4.1	5.1	15.2
4"	2.68	114.0	50.3	33.6	10.0	5.3	6.7	20.0
6"	Note 2	Note 2	Note 2	Note 2	15.1	8.0	10.1	30.2
8"	Note 2	Note 2	Note 2	Note 2	19.9	10.6	13.2	39.7
10"	Note 2	Note 2	Note 2	Note 2	24.9	13.3	16.6	49.9

Notes: 1) The BOCA National Plumbing Code
2) See data published by valve manufacturer

APPENDIX E
PIPING SIZING CHART

Dimensions and Weights

ɔuard Gold® pipe is produced (1/2" through 2") in .1 dimensions with CTS (Copper Tube Size) outside :ters. SDR, or Standard Dimension Ratio, means the hickness is directly proportional to the outside :ter. This results in all diameters carrying the same ɪre rating of 100 psi at 180°F.

(Table 4)

'lowGuard Gold® Pipe Dimensions & Weights SDR 11 (ASTM D 2846)

lominal Size Inches	Average OD Inches	Average ID Inches	Pounds per Ft. Empty	Pounds per Ft. Water Filled
1/2	0.625	0.489	0.084	0.163
3/4	0.875	0.715	0.141	0.311
1	1.125	0.921 0.46	0.232	0.513
1 1/4	1.375	1.125 0.56	0.347	0.767
1 1/2	1.625	1.329 0.66	0.486	1.071
2	2.125	1.739 0.67	0.829	1.831

ı® pipe is produced in a schedule system with *˙on Pipe Size)* outside diameters. This results in essure capability varying with the size of the pipe ıble 2).

(Table 5)

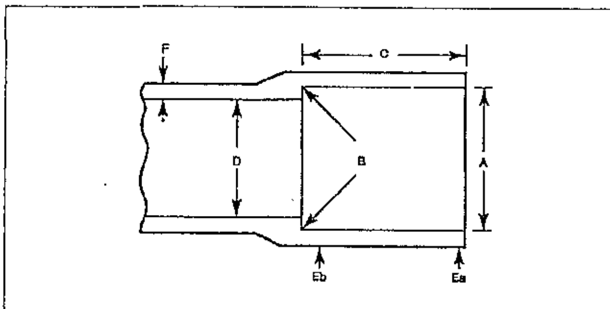
Corzan® Pipe Dimensions & Weights Schedule 80 (ASTM F 441)

ɔminal Size Inches	Average OD Inches	Average ID Inches	Pounds per Ft. Empty	Pounds per Ft. Water Filled
2 1/2	2.875	2.289	1.594	3.375
3	3.500	2.864	2.132	4.920
4	4.500	3.786	3.116	7.988
6	6.625	5.709	5.951	17.029
8	8.625	7.565	9.040	28.492
10	10.750	9.492	13.413	44.038
12	12.750	11.294	18.440	61.796
14	14.000	12.410	22.119	74.467
16	16.000	14.214	28.424	97.097

Fitting Dimensions

Figure 1.

Tapered Socket Dimensions for FlowGuard Gold® SDR 11, CPVC Tubing Fittings per ASTM D-2846*

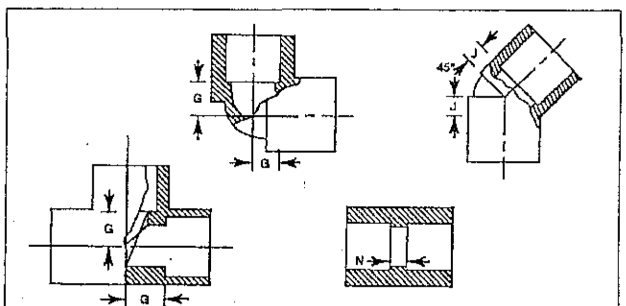


Nominal Size (in.)	Socket Entrance (A) I.D. Tolerance		Socket Bottom (B) I.D. Tolerance		(C) Min.	(D) Min.	(EA) Min.	(EB) Min.	(F) Min.
1/2	0.633	±0.003	0.619	±0.003	0.500	0.489	0.068	0.102	0.128
3/4	0.884	±0.003	0.870	±0.003	0.700	0.715	0.080	0.102	0.128
1	1.135	±0.003	1.121	±0.003	0.900	0.921	0.102	0.102	0.128
1 1/4	1.386	±0.003	1.372	±0.003	1.100	1.125	0.125	0.125	0.156
1 1/2	1.640	±0.004	1.622	±0.004	1.300	1.329	0.148	0.148	0.185
2	2.141	±0.004	2.123	±0.004	1.700	1.739	0.193	0.193	0.241

** All dimensions are in inches*

Figure 2.

Minimum Dimensions from Center to End of Socket (Laying Length) for FlowGuard Gold® SDR 11 CPVC Tubing Fitting per ASTM D-2846*

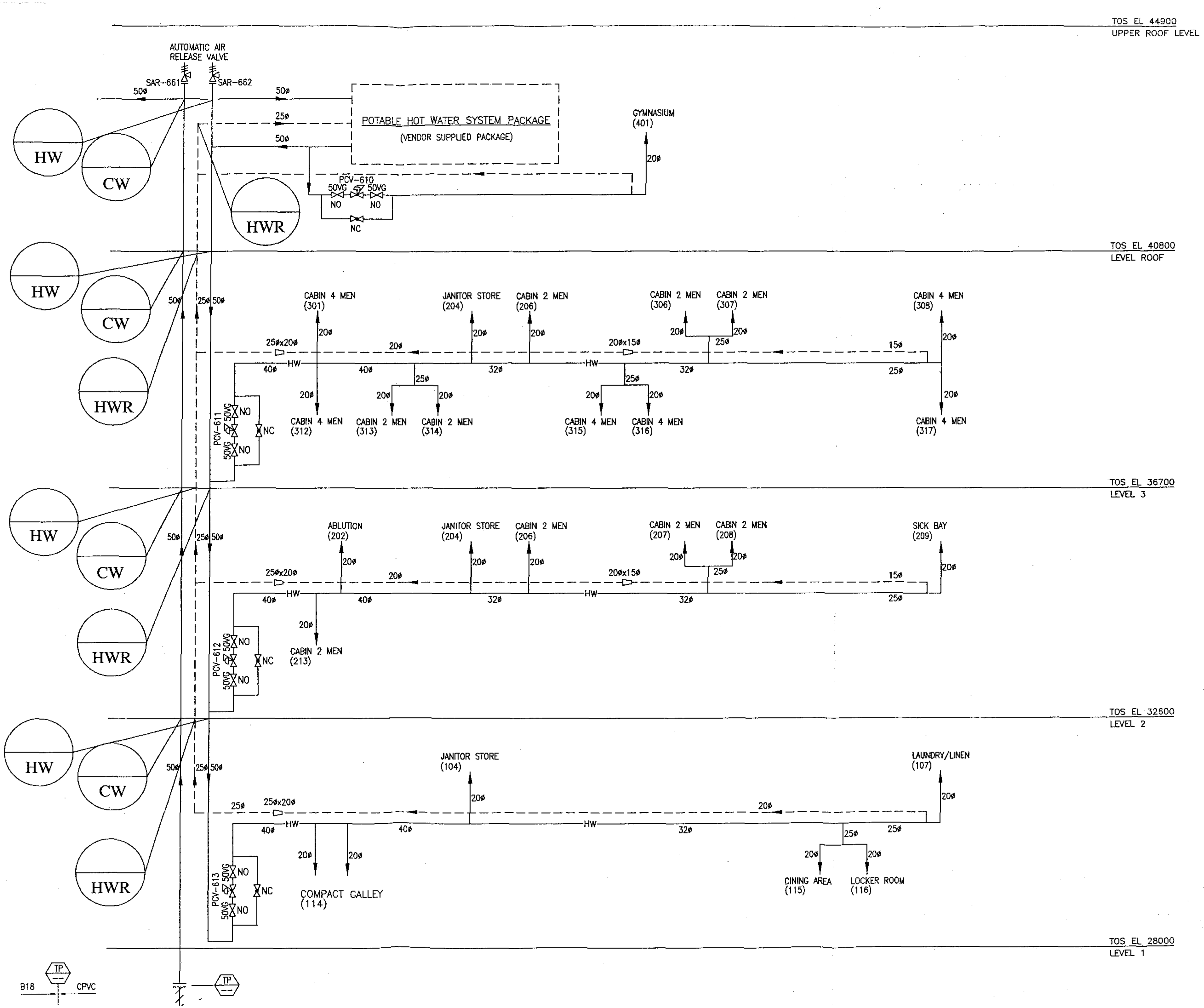


Nominal Size (in.)	(G) Min.	(J) Min.	(N) Min.
1/2	0.382	0.183	0.102
3/4	0.507	0.235	0.102
1	0.633	0.287	0.102
1 1/4	0.758	0.339	0.102
1 1/2	0.884	0.391	0.102
2	1.134	0.495	0.102

** All dimensions are in inches*

APPENDIX F

SYSTEM SCHEMATIC



GEND

- DENOTES OFFSHORE HOOK UP PIPEWORKS
- POTABLE HOT WATER SUPPLY PIPE
- POTABLE COLD WATER SUPPLY PIPE
- POTABLE RO WATER SUPPLY PIPE
- POTABLE HOT WATER RE-CIRCULATING PIPE
- BALL VALVE (VB)
- GATE VALVE (VG) / STOP COCK
- GLOBE VALVE (VGL)
- PRESSURE CONTROL VALVE (PCV)
- CONCENTRIC REDUCER (BF)
- AUTOMATIC AIR RELEASE VALVE
- NORMALLY CLOSE
- NORMALLY OPEN

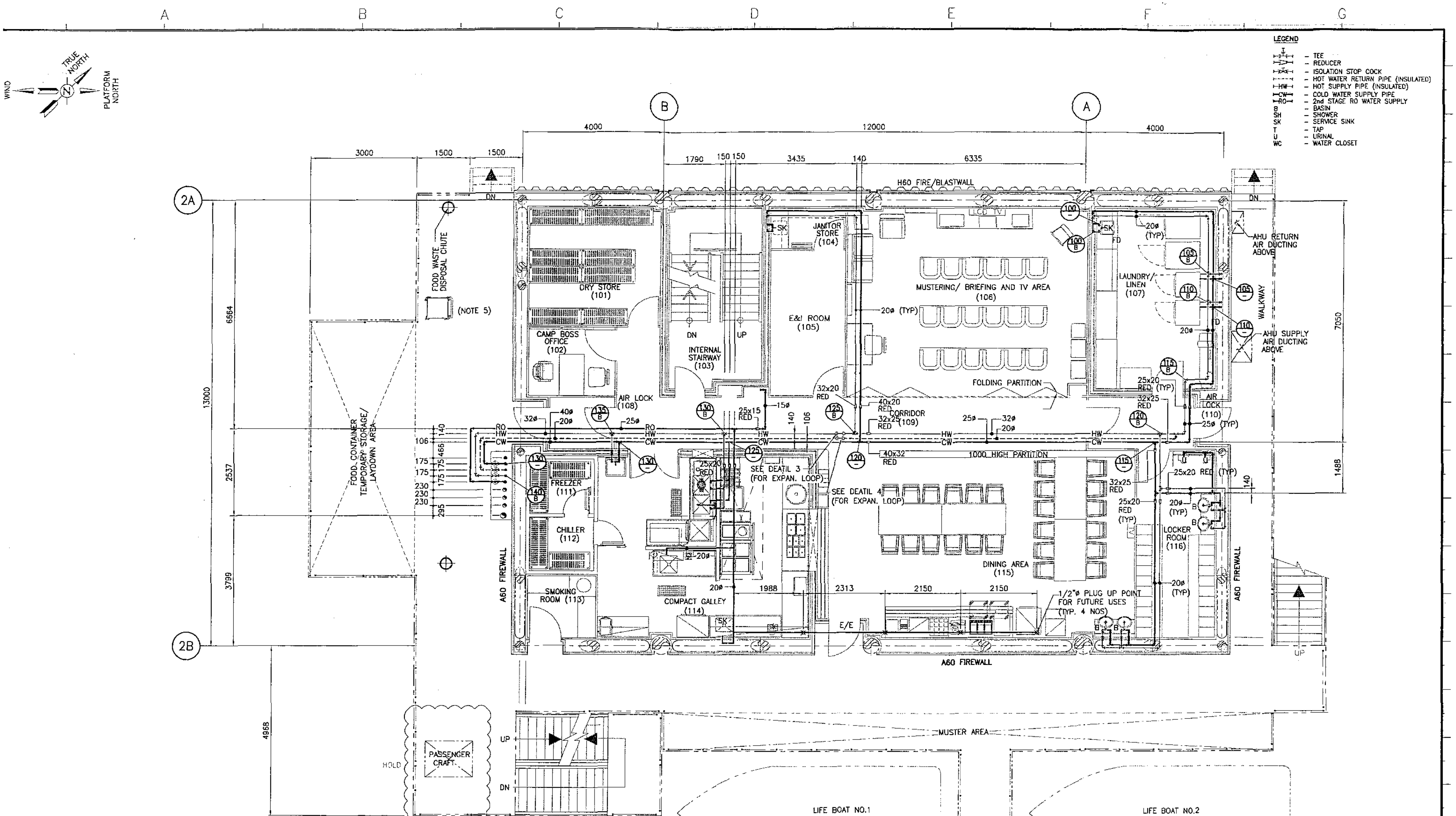


TABLE COLD & HOT WATER LINES SHALL BE CPVC PIPE TO ASTM D 2846 TO WITH DIMENSION (COPPER TUBE SIZE).
T WATER LINES SHALL BE INSULATED WITH 25mm THK. FIBERGLASS PIPE ION AND WRAPPED ALL AROUND WITH INSULATING CANVAS TAPE IN ACCORDANCE S 5422 AND BS 5970.
TABLE SERVICE WATER PIPES SHALL BE HYDROSTATICALLY TESTED TO 1.5 TIMES ITS WORKING PRESSURE TO A PERIOD OF 60 MINUTES WITHOUT ANY PRESSURE SE OR LEAKAGE.
G STOP COCK SHALL BE PROVIDED FOR ALL CABIN BATHROOM, LAUNDRY/LINEN ROOM, ROOM AND SERVICE PIPE SERVING THE GALLEY.
PPLY PIPES, EXCEPT FOR CONNECTIONS TO FIXTURES SHALL BE A LEAST MINIMUM . BORE.
OTHERWISE STATED, THE COLD AND HOT WATER UTILITY PIPING ARE RUNNING AT BOP 75 (LOW POINT) AND BOP EL 31975 (HIGH POINT).

LAYOUT PLAN – LEVEL 1 AT T.O.S. EL. (+) 28000

SCALE 1:50

THIS DRAWING IS FOR THE PURPOSE OF HYDRAULIC CALCULATION

0	23.05.10	APPROVED FOR CONSTRUCTION (AFC)	SI	FL	YKL	
A	14.05.10	ISSUED FOR APPROVAL (IFA)	SI	FL	YKL	AA
1A	23.04.10	ISSUED FOR CLIENT COMMENT (IFC)	SI	FELIX	YONG	
01	20.04.10	INTER-DISCIPLINE CHECK (IDC)	SI	FELIX	YONG	

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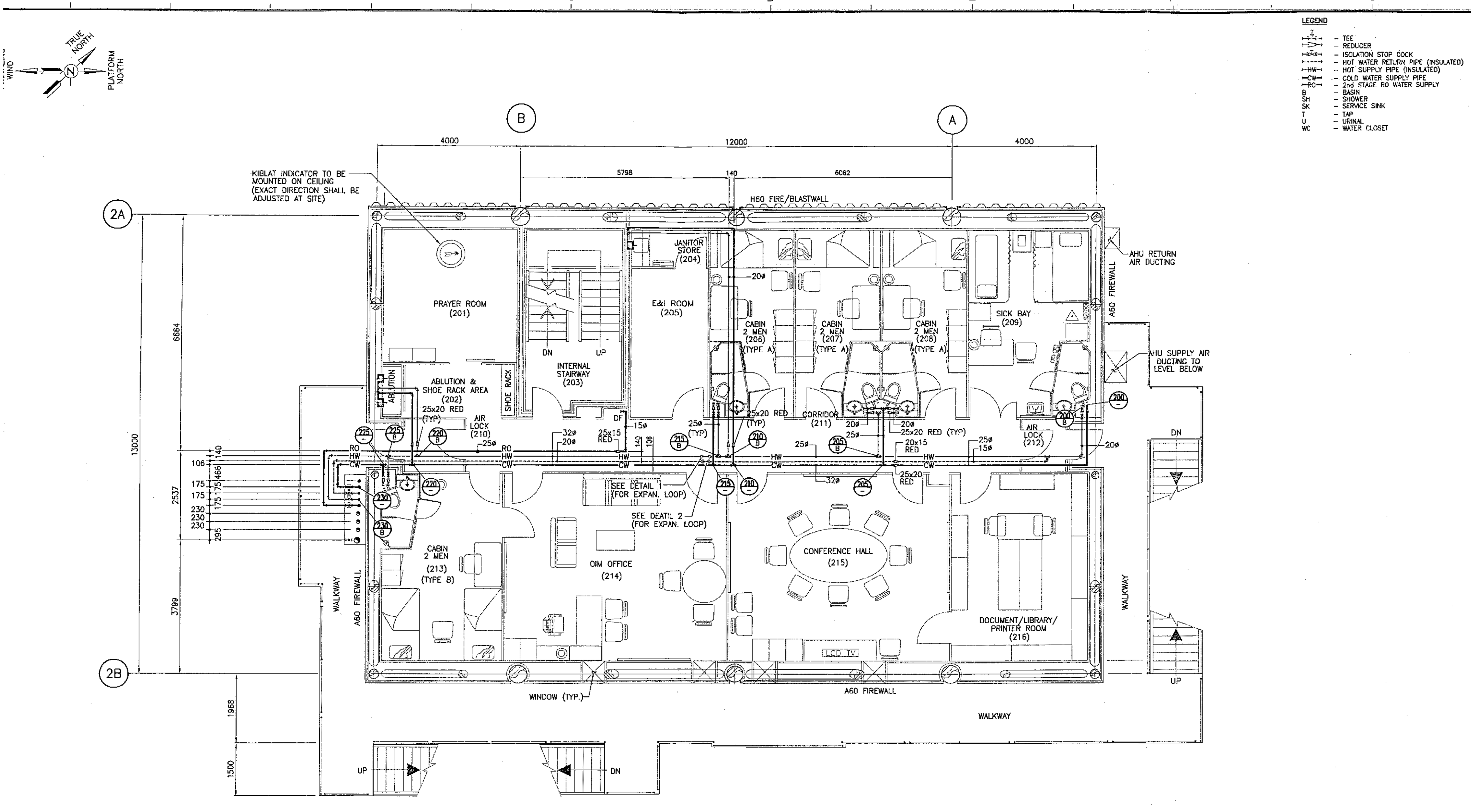
Level 20, Menara HLA
No.3 Jalan Kia Peng

SCALE : 1:50
DRAWN : SI
DATE : 8/6/10
PM329 EAST PIATU DEVELOPMENT PROJECT
PROJECT TITLE : DETAILED ENGINEERING DESIGN SERVICES
DRAWING TITLE : CPP LIVING QUARTERS
JOB NO. 103268
CONTRACT NO. C-NFX-PM323-P-8258
SHT. 1 OF 1



LAYOUT PLAN – LEVEL 2 AT T.O.S. EL. (+) 32600 (8 MEN)

SCALE 1:50

TABLF COLD & HOT WATER LINES SHALL BE CPVC PIPE TO ASTM D 2846 TO WITH DIMENSION (COPPER TUBE SIZE).

T WATER LINES SHALL BE INSULATED WITH 25mm THK. FIBERGLASS PIPE 'ION AND WRAPPED ALL AROUND WITH INSULATING CANVAS TAPE IN ACCORDANCE S 5422 AND BS 5970.

TABLF SERVICE WATER PIPES SHALL BE HYDROSTATICALLY TESTED TO 1.5 TIMES ' ITS WORKING PRESSURE TO A PERIOD OF 60 MINUTES WITHOUT ANY PRESSURE SE OR LEAKAGE.

IG STOP COCK SHALL BE PROVIDED FOR ALL CABIN BATHROOM, LAUNDRY/LINEN ROOM, ROOM AND SERVICE PIPE SERVING THE GALLEY.

PPLY PIPES, EXCEPT FOR CONNECTIONS TO FIXTURES SHALL BE A LEAST MINIMUM L BORE.

OTHERWISE STATED, THE COLD AND HOT WATER UTILITY PIPING ARE RUNNING AT BOP 75 (LOW POINT) AND BOP EL 36075 (HIGH POINT).

THIS DRAWING IS FOR THE PURPOSE OF HYDRAULIC CALCULATION

0	25.05.10	APPROVED FOR CONSTRUCTION (AFC)	SI	FL	YKL		
A	14.05.10	ISSUED FOR APPROVAL (IFA)	SI	FL	YKL	AA	
1A	23.04.10	ISSUED FOR CLIENT COMMENT (IFC)	SI	FELIX	YONG		
01	20.04.10	INTER DISCIPLINE CHECK (IDC)	SI	FELIX	YONG		
00	16.04.10	DISCIPLINE INTERNAL CHECK (DIC)	SI	FELIX	YONG		

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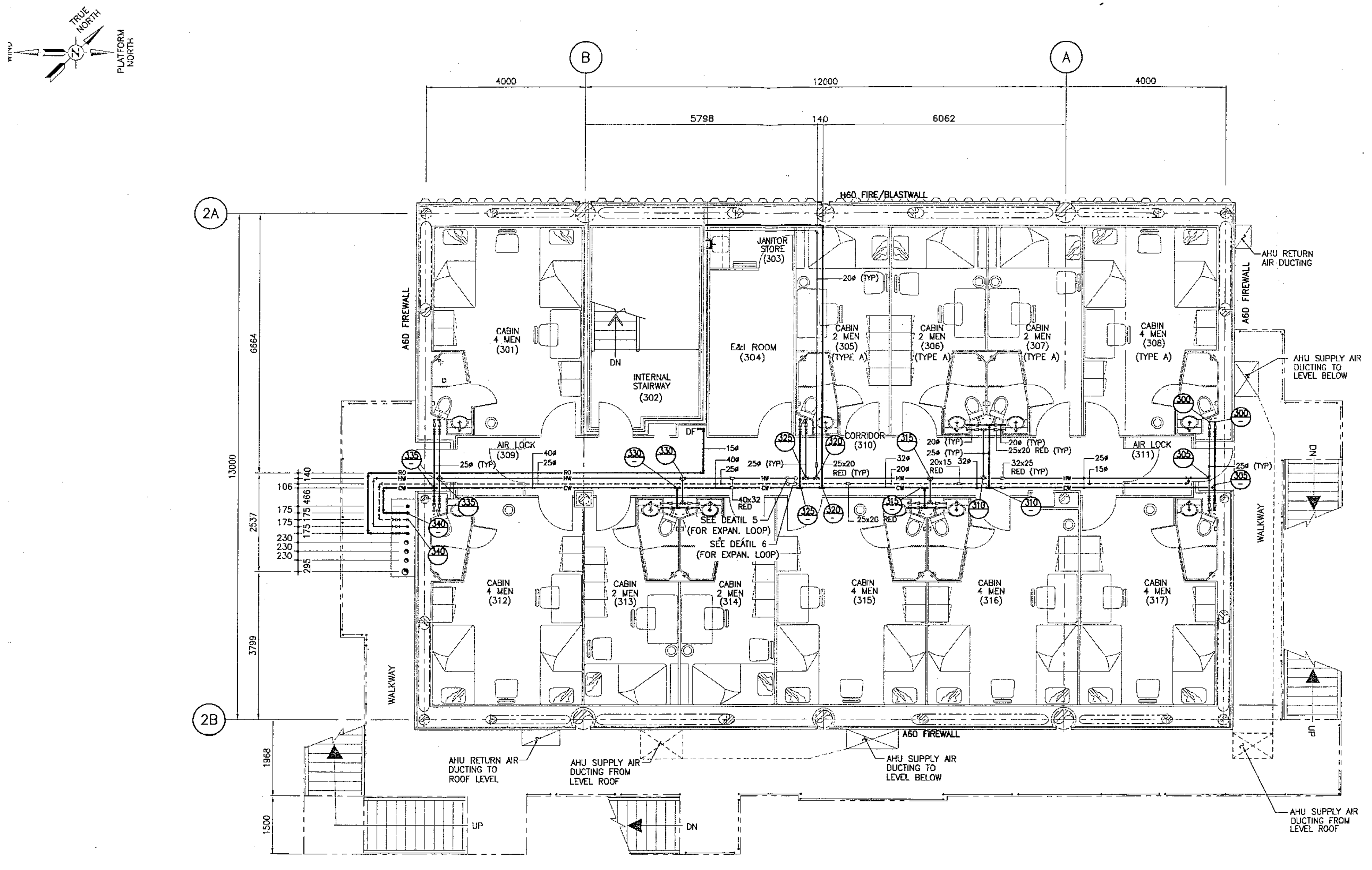
SCALE : 1:50	PM329 EAST PIATU DEVELOPMENT PROJECT
DRAWN : SI	PROJECT TITLE : DETAILED ENGINEERING DESIGN SERVICES
DATE : 8/6/10	
DRAWING TITLE :	CPP LIVING QUARTERS COLD AND HOT WATER PLUMBING

JOB NO.	103268
CONTRACT NO.	C-NFX-PM323-P-8258
SHT.	1 OF 1
DRAWING NO.	REV



LEGEND

- TEE
- REDUCER
- ISOLATION STOP COCK
- HOT WATER RETURN PIPE (INSULATED)
HW - HOT SUPPLY PIPE (INSULATED)
CW - COLD WATER SUPPLY PIPE
RO - 2nd STAGE RO WATER SUPPLY
B - BASIN
SH - SHOWER
SK - SERVICE SINK
T - TAP
U - URINAL
WC - WATER CLOSET

'ABLE COLD & HOT WATER LINES SHALL BE CPVC PIPE TO ASTM D 2846 TO WITH DIMENSION (COPPER TUBE SIZE).
' WATER LINES SHALL BE INSULATED WITH 25mm THK. FIBERGLASS PIPE
ON AND WRAPPED ALL AROUND WITH INSULATING CANVAS TAPE IN ACCORDANCE
5422 AND BS 5970.
'ABLE SERVICE WATER PIPES SHALL BE HYDROSTATICALLY TESTED TO 1.5 TIMES
ITS WORKING PRESSURE TO A PERIOD OF 60 MINUTES WITHOUT ANY PRESSURE
E OR LEAKAGE.
G STOP COCK SHALL BE PROVIDED FOR ALL CABIN BATHROOM, LAUNDRY/LINEN ROOM,
ROOM AND SERVICE PIPE SERVING THE GALLEY.
'PLY PIPES, EXCEPT FOR CONNECTIONS TO FIXTURES SHALL BE A LEAST MINIMUM
. BORE.
OTHERWISE STATED, THE COLD AND HOT WATER UTILITY PIPING ARE RUNNING AT BOP
'5 (LOW POINT) AND BOP EL 40175 (HIGH POINT).

LAYOUT PLAN – LEVEL 3 AT T.O.S. EL. (+) 36700 (34 MEN)

SCALE 1:50

THIS DRAWING IS FOR THE PURPOSE OF HYDRAULIC CALCULATION

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A	14.05.10	ISSUED FOR APPROVAL (IFA)	SI	FL	YKL	AA
1A	23.04.10	ISSUED FOR CLIENT COMMENT (IFC)	SI	FELIX	YONG	
01	20.04.10	INTER-DISCIPLINE CHECK (IDC)	SI	FELIX	YONG	
00	15.04.10	DISCIPLINE INTERNAL CHECK (DIC)	SI	FELIX	YONG	

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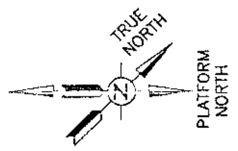
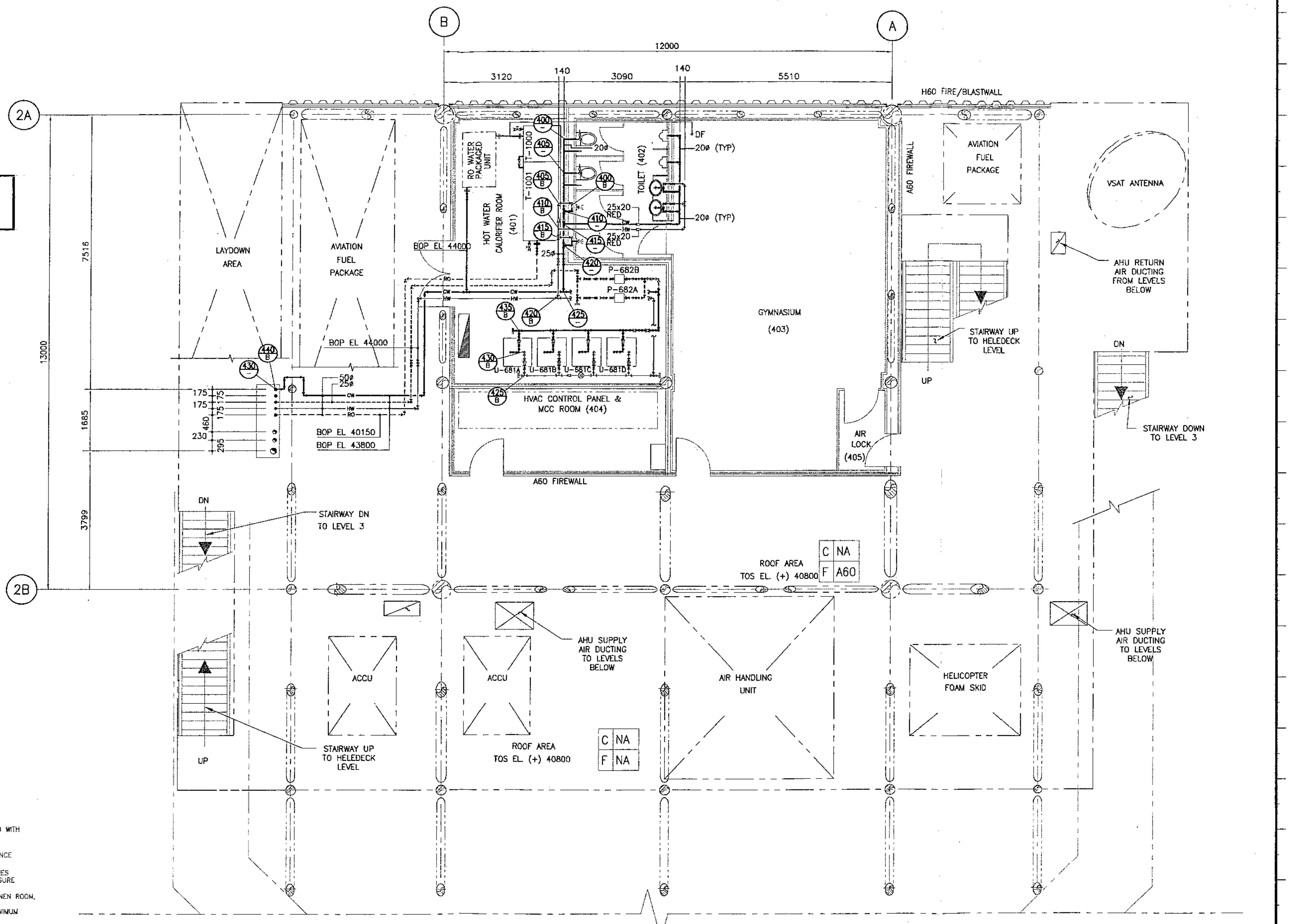
SCALE : 1:50
DRAWN : SI
DATE : 8/6/10

PM329 EAST PIATU DEVELOPMENT PROJECT
PROJECT TITLE : DETAILED ENGINEERING DESIGN SERVICES
DRAWING TITLE : CPP LIVING QUARTERS COLD AND HOT WATER PLUMBING

JOB NO. 103268
CONTRACT NO. C-NFX-PM323-P-8258
SHT. 1 OF 1
DRAWING NO.
REV



THIS DRAWING IS FOR THE PURPOSE OF HYDRAULIC CALCULATION



LAYOUT PLAN - ROOF LEVEL AT T.O.S. EL. (+) 40800

SCALE 1:50

TEE
REDUCER
ISOLATION STOP COCK
HOT WATER RETURN PIPE (INSULATED)
HOT SUPPLY PIPE (INSULATED)
COLD WATER SUPPLY PIPE
2nd STAGE RO WATER SUPPLY
BASIN
SHOWER
SERVICE SINK
TAP
URINAL
WATER CLOSET

3LE COLD & HOT WATER LINES SHALL BE CPVC PIPE TO ASTM D 2846 TO WITH TO CTS (COPPER TUBE SIZE).

WATER LINES SHALL BE INSULATED WITH 25mm THK. FIBERGLASS PIPE N AND WRAPPED ALL AROUND WITH INSULATING CANVAS TAPE IN ACCORDANCE 5422 AND BS 5970.

3LE SERVICE WATER PIPES SHALL BE HYDROSTATICALLY TESTED TO 1.5 TIMES TS WORKING PRESSURE TO A PERIOD OF 60 MINUTES WITHOUT ANY PRESSURE OR LEAKAGE.

STOP COCK SHALL BE PROVIDED FOR ALL CABIN BATHROOM, LAUNDRY/LINEN ROOM, OOM AND SERVICE PIPE SERVING THE GALLEY.

LY PIPES, EXCEPT FOR CONNECTIONS TO FIXTURES SHALL BE A LEAST MINIMUM 3ORE.

0	25.05.10	APPROVED FOR CONSTRUCTION (AFC)	SI	FL	YKL	AA	
A	14.05.10	ISSUED FOR APPROVAL (IFA)	SI	FL	YKL	AA	
1A	23.04.10	ISSUED FOR CLIENT COMMENT (IFC)	SI	FELIX	YONG		
01	20.04.10	INTER DISCIPLINE CHECK (IDC)	SI	FELIX	YONG		
00	16.04.10	DISCIPLINE INTERNAL CHECK (DIC)	SI	FELIX	YONG		
					DISC.	PROJ.	NFX

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SCALE : 1:50
DRAWN : SI
DATE : 8/6/10

PM329 EAST PIATU DEVELOPMENT PROJECT

PROJECT TITLE : DETAILED ENGINEERING DESIGN SERVICES

DRAWING TITLE : CPP LIVING QUARTERS COLD AND HOT WATER PLUMBING LAYOUT PLAN - ROOF LEVEL

JOB NO. 103268

CONTRACT NO. C-NFX-PM323-P-8258

SHT. 1 OF 2

DRAWING NO. FP-CPP-50-DR-0104C1

REV 0

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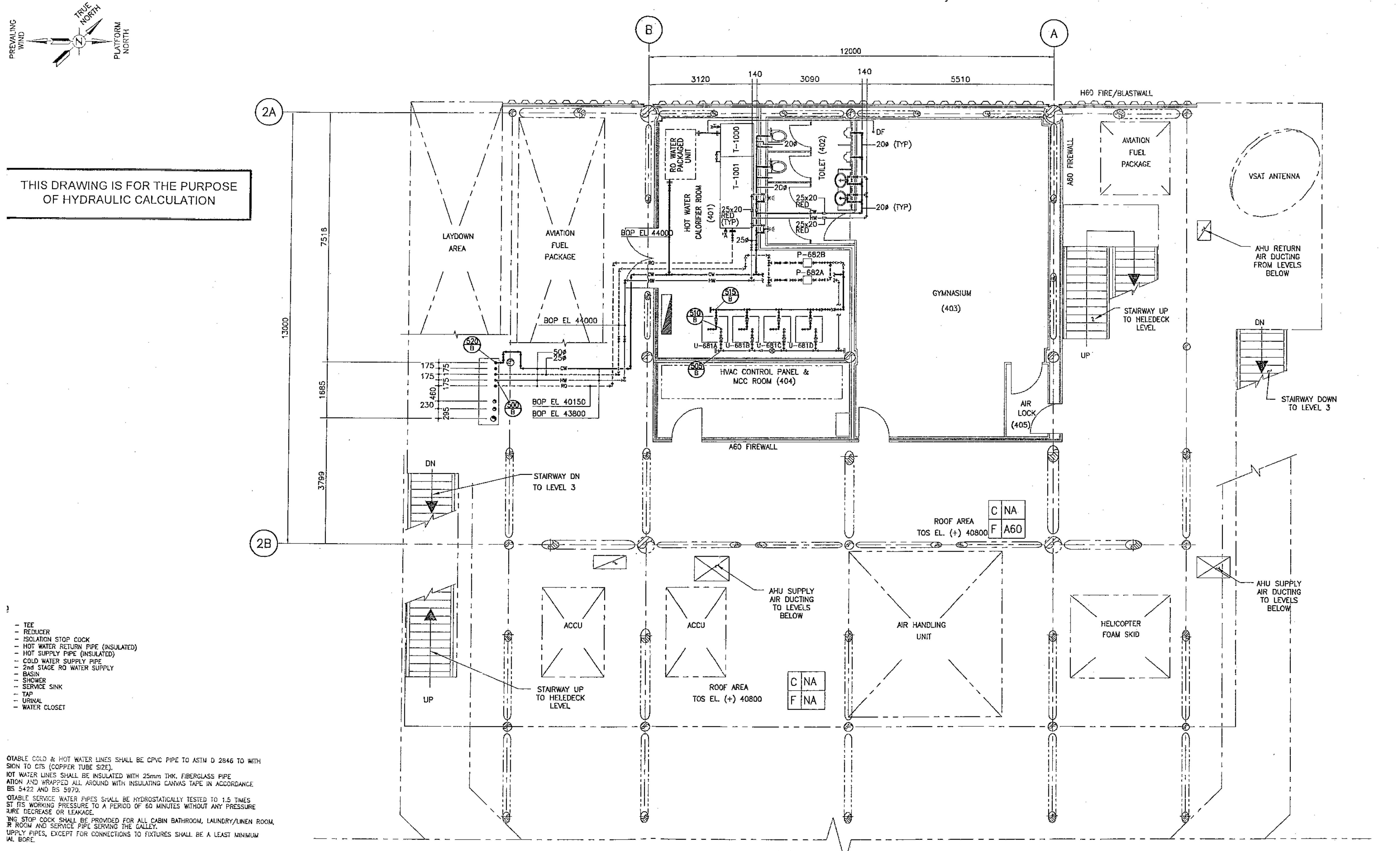

LAYOUT PLAN – ROOF LEVEL AT T.O.S. EL. (+) 40800

SCALE 1:50

- – TEE
- – REDUCER
- – ISOLATION STOP COCK
- – HOT WATER RETURN PIPE (INSULATED)
- – HOT SUPPLY PIPE (INSULATED)
- – COLD WATER SUPPLY PIPE
- – 2nd STAGE RO WATER SUPPLY
- – BASIN
- – SHOWER
- – SERVICE SINK
- – TAP
- – URINAL
- – WATER CLOSET

OTABLE COLD & HOT WATER LINES SHALL BE CPVC PIPE TO ASTM D 2846 TO WITH SION TO CTS (COPPER TUBE SIZE).

IOT WATER LINES SHALL BE INSULATED WITH 25mm THK. FIBERGLASS PIPE ATION AND WRAPPED ALL AROUND WITH INSULATING CANVAS TAPE IN ACCORDANCE BS 5422 AND BS 5970.

OTABLE SERVICE WATER PIPES SHALL BE HYDROSTATICALLY TESTED TO 1.5 TIMES ST ITS WORKING PRESSURE TO A PERIOD OF 60 MINUTES WITHOUT ANY PRESSURE SURE DECREASE OR LEAKAGE.

ING STOP COCK SHALL BE PROVIDED FOR ALL CABIN BATHROOM, LAUNDRY/LINEN ROOM, R ROOM AND SERVICE PIPE SERVING THE GALLEY.

UPPLY PIPES, EXCEPT FOR CONNECTIONS TO FIXTURES SHALL BE A LEAST MINIMUM AL BORE

0	25.05.10	APPROVED FOR CONSTRUCTION (AFC)	SI	FL	YKL	AA
A	14.05.10	ISSUED FOR APPROVAL (IFA)	SI	FL	YKL	AA
1A	23.04.10	ISSUED FOR CLIENT COMMENT (IFC)	SI	FELIX	YONG	
01	20.04.10	INTER-DISCIPLINE CHECK (IDC)	SI	FELIX	YONG	
00	16.04.10	DISCIPLINE INTERNAL CHECK (DIC)	SI	FELIX	YONG	

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SCALE : 1:50
DRAWN : SI
DATE : 2/6/10

PM329 EAST PIATU DEVELOPMENT PROJECT

PROJECT TITLE : DETAILED ENGINEERING DESIGN SERVICES

DRAWING TITLE : CPP LIVING QUARTERS COLD AND HOT WATER PLUMBING

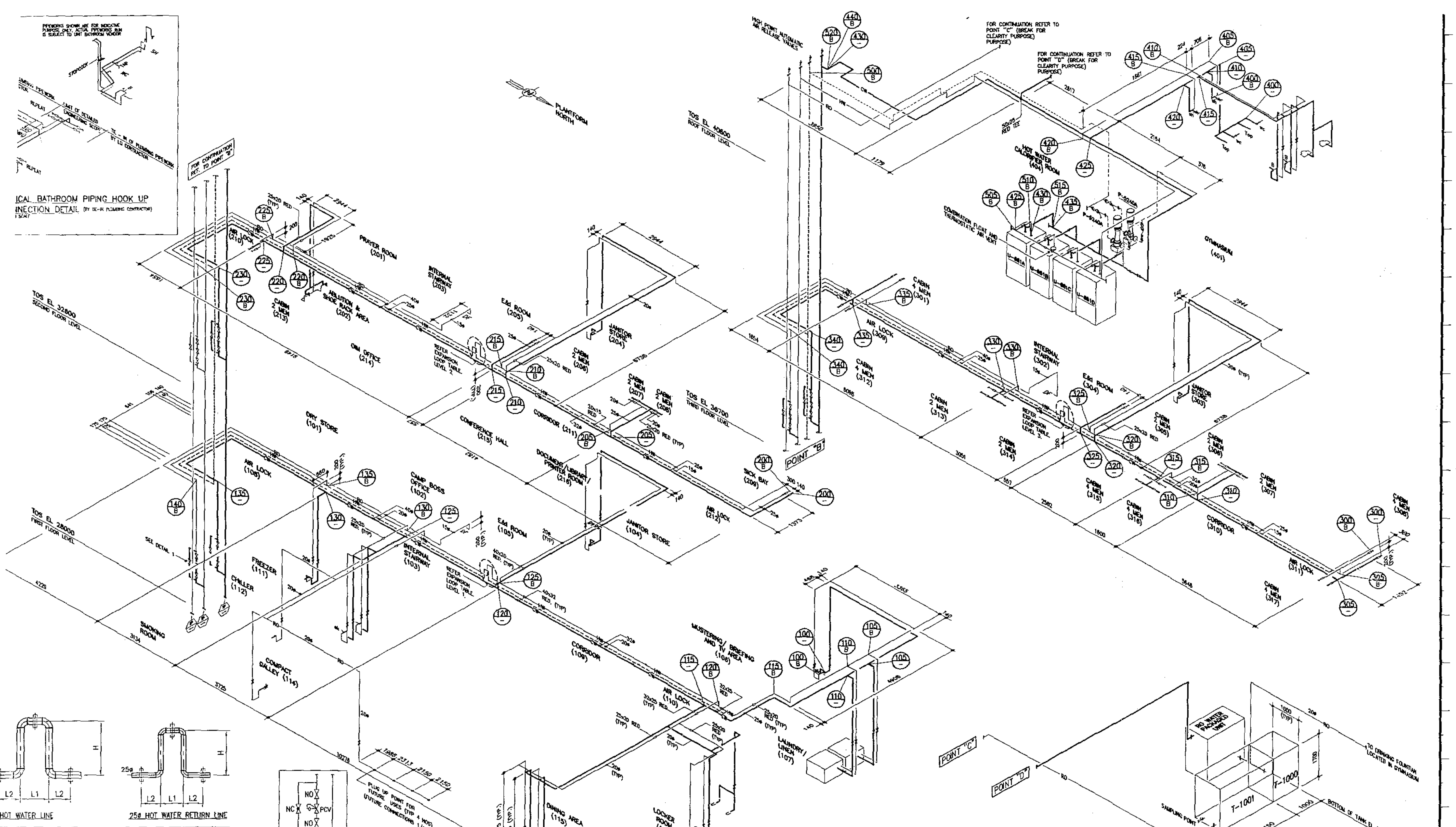
JOB NO. 103268

CONTRACT NO. C-NFX-PM323-P-8258

SHT. 2 OF 2

DRAWING NO.

REV



HOT WATER LINE

LQ. LEVEL	H	L1	L2(min.)
LEVEL 1	392.2	196.1	152.4
LEVEL 2	399.0	199.5	152.4
LEVEL 3	399.0	199.5	152.4
VERT. RISER	346.4	173.2	152.4

25⌀ HOT WATER RETURN LINE

LQ. LEVEL	H	L1	L2(min.)
LEVEL 1	323.2	161.6	152.4
LEVEL 2	323.2	161.6	152.4
LEVEL 3	326.7	163.3	152.4
VERT. RISER	278.6	139.3	152.4

EXPANSION LOOP TABLE

DETAIL 1

PRESSURE RECUCING SET C/W BYPASS

THIS DRAWING IS FOR THE PURPOSE OF HYDRAULIC CALCULATION

			BY	CHKD	DISC. APPR	PROJ. APPR	NFX APPR
0	31.05.10	APPROVED FOR CONSTRUCTION (AFC)	SI	FL	YKL	AA	
A	21.05.10	ISSUED FOR APPROVAL (IFA)	SI	FL	YKL	AA	
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01	20.04.10	INTER DISCIPLINE CHECK (IDC)	SI	FELIX	YONG		
00	15.04.10	DISCIPLINE INTERNAL CHECK (DIC)	SI	FELIX	YONG		

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50450 Kuala Lumpur, Malaysia

SCALE :
DRAWN :
DATE :

PM329 EAST PIATU DEVELOPMENT PROJECT

PROJECT TITLE : DETAILED ENGINEERING DESIGN SERVICES

DRAWING TITLE :
CPP LIVING QUARTERS
COLD AND HOT WATER PLUMBING
SYSTEM SCHEMATIC

JOB NO. 103268
CONTRACT NO. C-NFX-PM323-P-8258
SHT. 1 OF 1
DRAWING NO. EP-CPP-50-DR-0106C
REV 0

FILENAME - G:\PDMS\East Piatu Go By\Calculation Ref\EP-CPP-50-DR-0106C.dwg

Latest Update - June 8, 2010 - 6:13:11 PM

APPENDIX G

DETAILED CALCULATIONS – COLD AND HOT WATER SYSTEM

&

DETAILED CALCULATIONS – HEAT LOSS FOR EACH PIPE SIZE

Cold Water System

1	2	3	4	5	6	7 (5*6/100)	8	9 (7+8*6/100)
Nodes to Nodes	**No. Of LU**	**Design Flow Rates in GPM**	**Pipe Nominal Bore (in)**	**Actual Length of Pipe in Ft.**	**Head loss per 100 feet**	**Total loss of pipe**	**Head loss in equivalent length of pipe in feet (from fittings)**	**Total head loss**
LEVEL 2								
From equipment	6	4.76	¾	-	9.91	-	$3E + 2T_T + 1GV = 12.09$	1.20
200 – 205	6	4.76	1	24.41	2.89	0.705	$3E + 1T_T = 5.95$	0.88
205 – 210	18	6.69	1¼	13.72	3.94	0.541	$1T_T = 2.30$	0.63
210 – 215	23	7.40	1¼	1.83	3.94	0.072	$1T_T = 2.30$	0.16
215 – 220	29	8.15	1½	27.39	1.75	0.479	$1T_T = 2.68$	0.53
220 – 225	35	8.92	1½	2.63	1.75	0.046	$1T_T = 2.68$	0.09

225 – 230	41	10.1	1½	8.90	3.71	0.330	6E + 2T_T + 2GV + 1PCV = 21.1	1.11

For level 2, the furthest distance is from the WC 209 (flush valve) that needs 45 psi to operate.

Total head loss in friction for level 2 = 1.2 + 0.88 + 0.63 + 0.16 + 0.53 + 0.09 + 1.11

= 4.6 ft or 1.99 psi

Total psi for flush valve to operate = 1.99 + 45

= 46.99 psi

1	2	3	4	5	6	7 (5*6/100)	8	9 (7+8*6/100)
Nodes to Nodes	**No. Of LU**	**Design Flow Rates in GPM**	**Pipe Nominal Bore (in)**	**Actual Length of Pipe in Ft.**	**Head loss per 100 feet**	**Total loss of pipe**	**Head loss in equivalent length of pipe in feet (from fittings)**	**Total head loss**
LEVEL 3								
From equipment	6	4.76	¾	-	9.91	-	3E + 2T_T + 1GV = 12.09	1.19
300 – 305	6	4.76	1	5.91	2.89	0.171	2E + T_B = 8.05	0.40

305 – 310	12	5.33	1	18.53	4.05	0.750	T_T = 1.75	0.82
310 – 315	24	7.58	1¼	5.25	3.94	0.207	T_T = 2.30	0.30
315 – 320	36	9.29	1¼	8.47	3.94	0.334	T_T =2.30	0.42
320 – 325	41	10.15	1¼	1.83	8.35	0.153	T_T = 2.30	0.34
325 – 330	47	11.73	1½	10.01	3.71	0.371	T_T = 2.68	0.47
330 – 335	59	13.95	1½	20.01	3.71	0.742	T_T = 2.68	0.84
335 – 340	71	15.53	1½	8.90	6.33	0.563	6E + 2T_T + 2GV + 1PCV = 21.1	1.90

For level 3, the furthest distance is from the WC 308 (flush valve) that needs 45 psi to operate.

Total head loss in friction for level 3 = 1.19 + 0.40 + 0.82 + 0.30 + 0.42 + 0.34 + 0.47 + 0.84 + 1.90

= 6.68 ft or 2.89 psi

Total psi for flush valve to operate = 2.89 + 45

= 47.89 psi

1	2	3	4	5	6	7 (5*6/100)	8	9 (7+8*6/100))
Nodes to Nodes	**No. Of LU**	**Design Flow Rates in GPM**	**Pipe Nominal Bore (in)**	**Actual Length of Pipe in Ft.**	**Head loss per 100 feet**	**Total loss of pipe**	**Head loss in equivalent length of pipe in feet (from fittings)**	**Total head loss**
LEVEL 4								
400 – 405	3	4.76	¾	4.10	9.91	0.406	$1E + 2T_T = 3.84$	0.79
405 – 410	6	4.76	¾	12.49	9.91	1.238	$1E + 1T_T + 1T_B + 1GV = 7.14$	1.95
410 – 415	9	4.76	¾	1.14	9.91	0.113	$T_T = 1.37$	0.25
415 – 420	15	6.06	¾	1.91	18.47	0.353	$T_T = 1.37$	0.61
420 – 425	18	6.69	1	4.40	5.39	0.237	$2E + 1T_B = 8.05$	0.67
425 – 430	18	6.69	2	37.27	0.49	0.183	$6E + 1T_T = 20.01$	0.28

For level 4, the furthest distance is from the furthest WC (flush valve) that needs 45 psi to operate.

Total head loss in friction for level 4 = 0.79 + 1.95 + 0.25 + 0.61 + 0.67 + 0.28

= 4.55 ft or 1.97 psi

Total psi for flush valve to operate = 1.97 + 45

= <u>46.97 psi</u>

Abbreviation: E = Elbow

R = Reducer

TT = Standard Tee Through Flow

TB = Standard Flow Branch Flow

GV = Globe valve

CV = Check Valve

<u>Hot Water System</u>

1	2	3	4	5	6	7 (5*6/100)	8	9 (7+8*6/100)
Nodes to Nodes	**No. Of LU**	**Design Flow Rates in GPM**	**Pipe Nominal Bore (in)**	**Actual Length of Pipe in Ft.**	**Head loss per 100 feet**	**Total loss of pipe**	**Head loss in equivalent length of pipe in feet (from fittings)**	**Total head loss**
LEVEL 2								
From equipment	4.5	4.76	¾	-	9.91	-	$5E + 2T_T + 1T_B + 1GV = 12.91$	1.28
200B – 205B	4.5	4.76	1	23.61	2.89	0.682	$2E + 2T_T = 6.30$	0.86
205B – 210B	13.5	5.63	1¼	13.72	3.94	0.541	$1T_T = 2.30$	0.63
210B – 215B	18.5	6.69	1¼	0.91	3.94	0.036	$1T_T = 2.30$	0.13

215B – 220B	23	7.40	1½	28.57	1.75	0.500	$4E + 1T_T =$ 11.28	0.70
220B – 225B	29	8.32	1½	2.63	1.75	0.046	$1T_T = 2.68$	0.09
225B – 230B	33.5	8.72	1½	12.93	1.75	0.226	$6E + 2T_T + 2GV + PCV =$ 21.1	0.60

For level 2, the furthest distance is from the WC 209 (shower) that needs 12 psi to operate.

Total head loss for level 2 = 1.28 + 0.86 + 0.63 + 0.13 + 0.7 + 0.09 + 0.60
= 4.29 ft or 1.86 psi

Total psi for shower to operate = 1.86 + 12
= <u>13.86 psi</u>

1	2	3	4	5	6	7 (5*6/100)	8	9 (7+8*6/100)
Nodes to Nodes	**No. Of LU**	**Design Flow Rates in GPM**	**Pipe Nominal Bore (in)**	**Actual Length of Pipe in Ft.**	**Head loss per 100 feet**	**Total loss of pipe**	**Head loss in equivalent length of pipe in feet (from fittings)**	**Total head loss**
LEVEL 3								
From equipment	4.5	4.76	¾	-	9.91	-	$5E + 2T_T + 1T_B + 1GV = 12.91$	1.28

300B – 305B	4.5	4.76	1	5.08	2.89	0.147	2E + $1T_B$ = 8.05	0.38
305B – 310B	9	4.76	1	18.53	2.89	0.536	$2T_T$ = 3.50	0.64
310B – 315B	18	6.69	1¼	4.33	3.94	0.171	$1T_T$ = 2.30	0.26
315B – 320B	27	7.75	1¼	9.39	3.94	0.370	$1T_T$ = 2.30	0.46
320B – 325B	32	8.52	1¼	0.91	3.94	0.036	$1T_T$ = 2.30	0.13
325B – 330B	36.5	9.51	1¼	12.47	3.94	0.491	4E + $1T_T$ = 9.66	0.87
330B – 335B	45.5	11.41	1½	20.01	3.71	0.742	$1T_T$ = 2.68	0.84
335B – 340B	54.5	11.89	1½	12.93	3.71	0.480	6E + $2T_T$ + 2GV + PCV = 21.1	1.26

For level 3, the furthest distance is from the WC 308 (shower) that needs 12 psi to operate.

Total head loss in friction for level 2 = 1.28 + 0.38 + 0.64 + 0.26 + 0.46 + 0.13 + 0.87 + 0.84 + 1.26

= 6.12 ft or 2.65 psi

Total psi for shower to operate = 2.65 + 12

= 14.65 psi

1	2	3	4	5	6	7 (5*6/100)	8	9 (7+8*6/100)
Nodes to Nodes	**No. Of LU**	**Design Flow Rates in GPM**	**Pipe Nominal Bore (in)**	**Actual Length of Pipe in Ft.**	**Head loss per 100 feet**	**Total loss of pipe**	**Head loss in equivalent length of pipe in feet (from fittings)**	**Total head loss**
LEVEL 4								
400B – 405B	9	4.76	¾	2.15	9.91	0.213	3E = 3.3	0.54
405B – 410B	9	4.76	1	2.32	2.89	0.067	$1T_T$ = 1.75	0.12
410B – 415B	15	6.06	1	0.73	5.39	0.039	$1T_T$ = 1.75	0.13
415B – 420B	18	6.69	1	5.69	5.39	0.307	2E + $1T_B$ = 8.05	0.74
420B – 425B	18	6.69	2	25.05	0.49	0.123	1E + $3T_T$ + $2T_B$ = 33.71	0.29
425B – 430B	18	6.69	1	2.10	5.39	0.113	1ST + 1BV = 30.17	1.73
430B – 435B	18	6.69	1	2.71	5.39	0.146	1E + $1T_B$ + 1CV = 15.39	0.98
435B – 440B	18	6.69	2	59.79	0.49	0.293	7E + $2T_B$ + $5T_T$ + 1CV + 1BV = 132.97	0.94

For level roof the furthest distance is from the furthest shower that needs 12 psi to operate.

Total head loss in friction for level 4 = 0.54 + 0.12 + 0.13 + 0.74 + 0.29 + 1.73 + 0.98 + 0.94

= 5.77 ft or 2.50 psi

Total psi for shower to operate = 2.50 + 12

= 14.50 psi

1	2	3	4	5	6	7 (5*6/100)	8	9 (7+8*6/100))
Nodes to Nodes	**No. Of LU**	**Design Flow Rates in GPM**	**Pipe Nominal Bore (in)**	**Actual Length of Pipe in Ft.**	**Head loss per 100 feet**	**Total loss of pipe**	**Head loss in equivalent length of pipe in feet (from fittings)**	**Total head loss**
LEVEL 4 (from cold water system back to hot water)								
500B – 505B	18	6.69	2	59.96	0.49	0.294	$5E + 2T_B + 4T_T = 48.2$	0.53
505B – 510B	18	6.69	1	2.10	5.39	0.113	1ST + 1BV = 30.17	1.74
510B – 515B	18	6.69	1	2.71	5.39	0.146	$1E + 1T_B + 1CV = 15.39$	0.98

515B – 520B	18	6.69	2	59.79	0.49	0.293	$7E + 2T_B + 5T_T + 1CV + 1BV =$ 132.97	0.94

From the cold water system to hot water system back to the first pipe on level 4

Total head loss in friction = 0.53 + 1.74 + 0.98 + 0.94

= 4.19 ft or 1.81 psi

Abbreviation: E = Elbow

R = Reducer

TT = Standard Tee Through Flow

TB = Standard Flow Branch Flow

GV = Globe valve

CV = Check Valve

<u>COLD WATER SYTEM USING PRESSURE ASSISTED VALVE</u>

For level 3, the furthest distance is from the WC 308 (flush valve) that needs 45 psi to operate.

Total head loss in friction for level 3 = 1.19 + 0.40 + 0.82 + 0.30 + 0.42 + 0.34 + 0.47 + 0.84 + 1.90

= 6.68 ft or 2.89 psi

Total psi for pressure assisted valve to operate = 2.89 + 30

= <u>32.89 psi</u>

For level 4, the furthest distance is from the furthest WC (flush valve) that needs 45 psi to operate.

Total head loss in friction for level 4 = 0.79 + 1.95 + 0.25 + 0.61 + 0.67 + 0.28

= 4.55 ft or 1.97 psi

Total psi for flush valve to operate = 1.97 + 30

= <u>31.97 psi</u>

<u>COLD WATER SYTEM USING GRAVITY FLUSH TANK</u>

For level 3, the furthest distance is from the WC 308 (flush valve) that needs 45 psi to operate.

Total head loss in friction for level 3 = 1.19 + 0.40 + 0.82 + 0.30 + 0.42 + 0.34 + 0.47 + 0.84 + 1.90

= 6.68 ft or 2.89 psi

Total psi for gravity flush tank to operate = 2.89 + 10

= <u>12.89 psi</u>

For level 4, the furthest distance is from the furthest WC (flush valve) that needs 45 psi to operate.

Total head loss in friction for level 4 = 0.79 + 1.95 + 0.25 + 0.61 + 0.67 + 0.28

= 4.55 ft or 1.97 psi

Total psi for gravity flush tank to operate = 1.97 + 10

= <u>11.97 psi</u>

<u>HEAT LOSS CALCULATIONS FOR EACH PIPE SIZE</u>

Using Flow Guard Gold Pipe and Fittings Manual, the pipe dimension and weights can be known. Based on ASTM D 2846

For ½ inch pipe, outside diameter OD = 0.625 inch
= 0.625/ 12
= 0.0521 feet

$A = \pi$ (OD) L

Looking for the convective heat loss of the pipe per foot run, so length of the pipe is 1ft

So A $= \pi$ (0.0521 ft) (1 ft)
$= 0.1636$ ft^2

T_2 = 21 °C
= 70 °F

T_1 = 60 °C
= 140 °F

Q = -h (A) ($T_2 - T_1$)
= (-2.643421 BTU/hr-ft^2 -°F-in) (0.0.1636 ft^2) (70 °F -140 °F)
= 30.27 BTU/hr

For ¾ inch pipe, outside diameter OD = 0.875 inch
= 0.875/ 12
= 0.0729 feet

$A = \pi$(OD) L

Looking for the convective heat loss of the pipe per foot run, so length of the pipe is 1ft

So A $= \pi$(0.0729 ft) (1ft)
$= 0.229$ ft^2

T_2 = 21 °C
= 70 °F

T_1 = 60 °C
= 140 °F

Q = -h (A) ($T_2 - T_1$)
= (-2.643421BTU/hr-ft^2 -°F-in) (0.229 ft^2) (70 °F -140 °F)
= 42.384 BTU/hr

For 1 inch pipe, outside diameter OD = 1.125 inch
= 1.125/ 12
= 0.09375 feet

$A = \pi$ (OD) L

Looking for the convective heat loss of the pipe per foot run, so length of the pipe is 1ft

So A $= \pi$ (0.09375 ft) (1ft)
$= 0.295$ ft^2

T_2 = 21 °C
= 70 °F

T_1 = 60 °C
= 140 °F

$$Q = -h(A)(T_2 - T_1)$$
$$= (-2.643421 \text{ BTU/hr-ft}^2\text{-}^\circ\text{F-in})(0.295 \text{ ft}^2)(70\ ^\circ\text{F} - 140\ ^\circ\text{F})$$
$$= 54.587 \text{ BTU/hr}$$

For 1¼ inch pipe, outside diameter OD= 1.375 inch
= 1.375/ 12
= 0.1146 feet

$A = \pi (OD) L$

Looking for the convective heat loss of the pipe per foot run, so length of the pipe is 1ft

So $A = \pi (0.1146 \text{ ft})(1 \text{ ft})$
$= 0.360 \text{ ft}^2$

$T_2 = 21\ ^\circ\text{C}$
$= 70\ ^\circ\text{F}$

$T_1 = 60\ ^\circ\text{C}$
$= 140\ ^\circ\text{F}$

$$Q = -h(A)(T_2 - T_1)$$
$$= (-2.643421 \text{ BTU/hr-ft}^2\text{-}^\circ\text{F-in})(0.360 \text{ ft}^2)(70\ ^\circ\text{F} - 140\ ^\circ\text{F})$$
$$= 66.609 \text{ BTU/hr}$$

For 1½ inch pipe, outside diameter OD = 1.625 inch
= 1.625/ 12
= 0.1354 feet

$A = \pi (OD) L$

Looking for the convective heat loss of the pipe per foot run, so length of the pipe is 1ft

So $A = \pi (0.1354 \text{ ft})(1 \text{ ft})$
$= 0.425 \text{ ft}^2$

$T_2 = 21\ ^\circ\text{C}$
$= 70\ ^\circ\text{F}$

$T_1 = 60\ ^\circ\text{C}$
$= 140\ ^\circ\text{F}$

$$Q = -h(A)(T_2 - T_1)$$
$$= (-2.643421 \text{ BTU/hr-ft}^2\text{-}^\circ\text{F-in})(0.425 \text{ ft}^2)(70\ ^\circ\text{F} - 140\ ^\circ\text{F})$$
$$= 78.720 \text{ BTU/hr}$$

For 2 inch pipe, outside diameter OD = 2.125 inch
= 2.125/ 12
= 0.1771 feet

$A = \pi (OD) L$

Looking for the convective heat loss of the pipe per foot run, so length of the pipe is 1ft

So A $= \pi\ (0.1771)\ (1)$
$= 0.556\ ft^2$

$T_2 = 21\ ^oC$
$= 70\ ^oF$
$T_1 = 60\ ^oC$
$= 140\ ^oF$

$Q = -h\ (A)\ (T_2 - T_1)$
$= (-2.643421\ BTU/hr\text{-}ft^2\ \text{-}^oF\text{-}in)\ (0.556\ ft^2)\ (70\ ^oF - 140\ ^oF)$
$= 102.941\ BTU/hr$